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EXPERIMENTAL DOMESTIC SCIENCE



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Experimental Domestic Science

By

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PREFACE

IT has only recently been recognised that Domestic subjects form a wide field for practical and utilitarian science. Many authorities are now convinced that science can be directly and adequately taught in the kitchen ; that a previous training in elementary science is not indispensable, as the principles of science can often be made quite clear by drawing upon everyday experience, and largely by the aid of kitchen utensils and commodities.

This little book, intended primarily for Domestic Science Schools and Girls' Schools generally, provides a suggested course based upon this view, for all interested in the domestic and culinary arts. It is founded upon a short course of lectures on Experimental Domestic Science delivered to the Domestic Science teachers of Preston and district. Although its " format " is that of a text book, the original lecture form has been for the most part retained ; it is, therefore, with intent, less formal and more discursive than the text book proper, so that it can appeal not only to Domestic Science students but also to the general public.

The chapters on elementary physics, chemistry and popular fallacies are not intended to be exhaustive and complete, but aim at stimulating thought and interest in science and at arousing a desire for closer study.

In expressing the hope that the book (essentially the first of its kind) will fulfil the aim with which it has been written, I have great pleasure in acknowledging my indebtedness to Mr. J. Best, B.Sc., Educational Editor to Mr. Heinemann, for many valuable suggestions and help throughout.

R. H. J.

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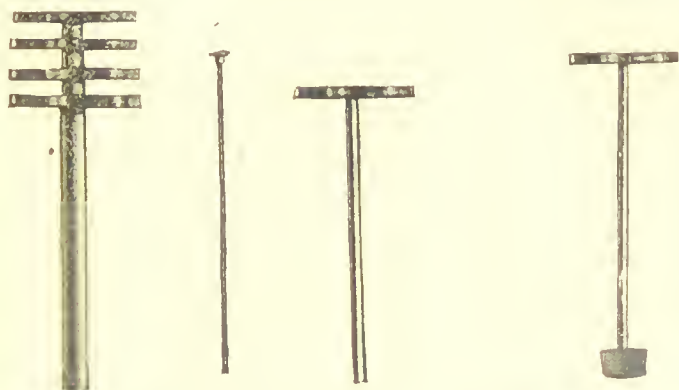
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INTRODUCTORY

A FEW POINTS ON MANIPULATION, AND FITTING-UP OF APPARATUS

(1) To fit a cork in a bottle, flask, or other vessel, choose a cork a little too big at first. Place it on the floor and gently roll it to and fro underneath the foot, pressing all the time, but not enough to break the cork. Wipe with a duster. The cork should now fit the bottle or flask sufficiently easily. In no case must it fit too loosely.

(2) To bore a hole in a cork, choose a borer (see Fig. 1), rather narrower than the hole required. Most borers have



Cork Borers and Cleaning Rod.

Boring a Hole in a Cork.

FIG. 1.

a hole pierced near the top so that a metal bar (the cleaning rod) can pass through and thus act as a handle. In Fig. 1, the handle is permanently attached to the

D.S.

B

apparatus, and the rod is used for cleaning purposes only. Fit the metal bar through the top of the borer and place the cork on the table. Now press the borer vertically on the cork and by pressure and twisting bore right through.

Any tubes, etc., requiring to be fixed in the cork must fit tightly into the hole, and when once fitted into position, be difficult to move.

(3) To bend glass tubing, light an ordinary fish-tail gas-burner and hold a sufficient length of the glass tube required

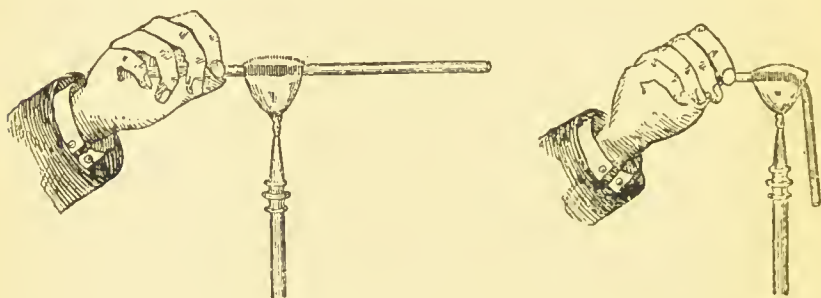


FIG. 2.—Bending a piece of Glass Tubing.

to be bent, above the blue part of the flame, and just in the yellow portion. The tube must be held horizontally (see Fig. 2).

In a few seconds, the glass becomes soft, and then, by its own weight, bends. When the required angle is obtained, take the tube out of the flame, cool, and wipe away the soot with a piece of paper, finishing with first a moist duster and then a dry one.

(4) To cut glass tubing any required length, make a slight scratch upon it with one edge of a fine sharp three-cornered file. Hold the tubing with the left hand about an inch one side of the scratch, and the right hand the same distance to the right of the file mark. Break the tube across by gently pulling and bending, almost exactly as one would snap a thin piece of wood.

CHAPTER I

Density and specific gravity of liquids and beverages—The principal ingredients of milk, their nature and amounts—Simple tests for the different food-stuffs—Adulteration and contamination of milk a serious offence.

Density.—Everyone is familiar with the beverages water, milk, tea, coffee, and cocoa, and knows that a large cup of one of these liquids holds more than a smaller one. Suppose, for example, we are dealing with milk, and an egg-cup, a tea-cup, and a jug. If the vessels are weighed empty on a pair of scales or a spring balance (Fig. 3), and then again weighed filled with the milk, the weight of the milk in each of the three vessels is obtained, *i.e.*, the total amount of material of milk in one egg-cup, one tea-cup, or one jug. Note carefully that the quantity of material in *one* measureful only of the vessels is being considered.

If, in describing milk, we say that it weighs 2 ozs., 6 ozs., or 2 lbs., these three different weights convey no clear meaning. But if we say that the quantity of material of milk is—

2 ozs. per egg-cupful and the egg-cup is produced,					
or 6 ozs. „ tea-cupful	„	tea-cup	„	„	
or 2 lbs. „ jugful	„	jug	„	„	

then there is a very definite connection between the quantity of material as given by the weight, and the volume as indicated by the size of the vessel containing it. **When the amount of material in anything (as expressed by its weight)**

is connected with a specified unit volume of it, this combination is known as **Density**. For example, in the figures given above, *the Density of milk equals 2 ozs. per egg-cupful, or 6 ozs. per tea-cupful, or 2 lbs. per jugful.*

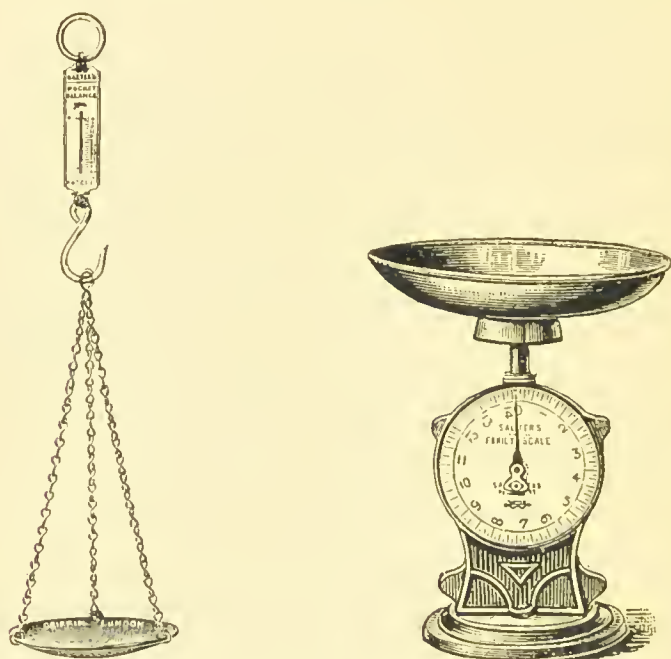


FIG. 3.—Spring Balance and Pan.

In each case the particular vessel used must be exhibited, as egg-cups, tea-cups, and jugs are not made to any one recognised size. It will thus be seen that in the determination of the density of one particular substance, different results are obtained according to the vessels used.

Examples of experiments :—

Weight of egg-cup	...	...	...	ozs.
" " "	filled with milk	...		$1\frac{1}{2}$
				$3\frac{1}{2}$

∴ the weight of the egg-cupful of milk is 2 ozs. and the density of the milk is 2 ozs. per egg-cupful.

Weight of tea-cup	ozs.
Weight of tea-cup	$3\frac{1}{2}$
Weight of tea-cup filled with milk ...	$12\frac{1}{4}$

∴ the weight of the tea-cupful of milk is $8\frac{3}{4}$ ozs. and the density of the milk is $8\frac{3}{4}$ ozs. per tea-cupful.

Weight of jug	lbs.	ozs.
Weight of jug	1	$10\frac{3}{4}$
Weight of jug filled with milk ...	3	$10\frac{3}{4}$

Whence the weight of the jugful of milk is 2 lbs., and the density of the milk is 2 lbs. per jugful.

(Keep the egg-cup, the tea-cup, and the jug for reference and for other experiments.)

Expt. 1. Perform similar experiments with water, tea, coffee, and cocoa, using the above vessels, and thus determine their densities. Carefully record the results in the manner shown above. Then place all the figures connected with the egg-cup together, and do the same for the tea-cup and the jug. *Remember that the vessels must be kept;* otherwise the value of the work will disappear.

To avoid the necessity of referring to a cup or other vessel a definite unit volume is agreed upon in science, which can at once be understood without mentioning a model, such as a cup. Reference to this unit, however, is not essential so long as all vessels are kept, or can be referred to at any time.

As will be seen from the next paragraph, this unit volume is the amount of space occupied by unit weight of water.

Specific Gravity or Relative Density.—It will be noticed from the experiments that the densities of the beverages dealt with are almost the same as those of water for each particular vessel used. In some cases, perhaps, no difference will be observed owing to the scales or balance not being sufficiently sensitive. As we now particularly desire to notice any difference, it will be better to use a larger vessel for the weighing and thus make the difference more obvious.

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Expt. 2. Choose a large bottle with a narrow neck, or a decanter with a neck almost equally narrow (see Fig. 4). Weigh the clean, dry, empty vessel, and then weigh filled with water; next with each of the beverages in turn,



Bottle with Narrow Neck.



Decanter with Narrow Neck.

FIG. 4.

rinsing out each time before filling. Record these weights. Now divide each of the weights of milk, tea, coffee, and cocoa, by the weight of water, not forgetting the weight of the empty vessel. The number obtained in this way is called the **Specific Gravity or Relative Density** of that liquid.

Examples of experiments :—

	lbs. ozs.
Weight of clean, dry decanter ...	1 1 $\frac{3}{4}$
" " " " filled with	
water	2 8 $\frac{1}{4}$
∴ the weight of the decanter of	
water is	1 6 $\frac{1}{2}$
Weight of decanter filled with milk ...	2 9
∴ the weight of the decanterful of	
milk is	1 7 $\frac{1}{4}$
Weight of the decanterful of milk	1 7 $\frac{1}{4}$
Weight of the decanterful of water =	1 6 $\frac{1}{2}$
$= \frac{23\frac{1}{4} \text{ ozs.}}{22\frac{1}{2} \text{ ozs.}} = \frac{93}{90} = 1.033.$	

The specific gravity of milk = 1.033.

Expt. 3. In a similar manner determine the specific gravities of tea, coffee, and cocoa, using the same decanter or bottle throughout. How would the ultimate result be affected by using throughout another vessel for all the weighings?

An examination of the specific gravities will reveal the fact that they are *very slightly* more than one, *i.e.*, the beverages have, bulk for bulk, almost the same weight as water. The reason for this, except in the case of milk, is obvious, as tea, coffee, and cocoa are made with water. We will now confine our attention to milk.

It has been found that the specific gravity of the sample of milk used was 1.033 (see p. 6). Either milk is *one* liquid of very nearly the same density as water, or else it *contains* a large quantity of water. Which of the two is the case?

Expt. 4. Pour a little water in a kettle (not quite reaching the bottom of the spout inside), boil on a ring

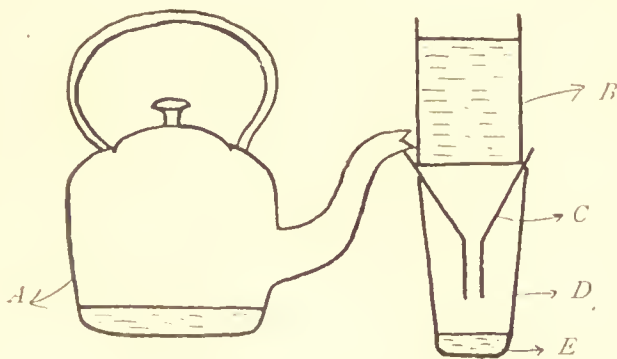


FIG. 5.

- A. Kettle heated on Ring Burner or Fire.
- B. Tin Can containing Cold Water.
- C. Tin Funnel.
- D. Large Tumbler or Glass Vessel.
- E. Condensed Steam.

burner, or on a fire, and allow the steam which issues to impinge on a tin can (containing cold water) resting on a

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tin funnel supported on a tumbler (see Fig. 5). A colourless liquid collects; *it is water*.

Expt. 5. Repeat the experiment, using salty water. Is the water collected in the tumbler salty or not?

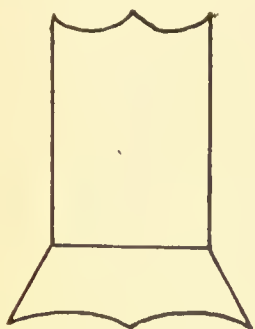


FIG. 6.—A Cascade Boiler.

When water boils, water may be regained from it and collected by cooling the steam with a cold tin. If milk is *one* liquid altogether distinct from water, *milk* ought to collect in the tumbler. (As milk invariably “boils over” when heated in the ordinary way, it is necessary to use some device for preventing this. A “cascade boiler,” made of earthenware and costing a few pence, acts very well (see Fig. 6). The scientific explanation of the “boiling over” of milk is not

easy to supply. It is well known that a skin forms over milk when it is heated, and this might encase the bubbles of steam, and by a sudden bursting of the bubbles cause the familiar phenomenon. Against this

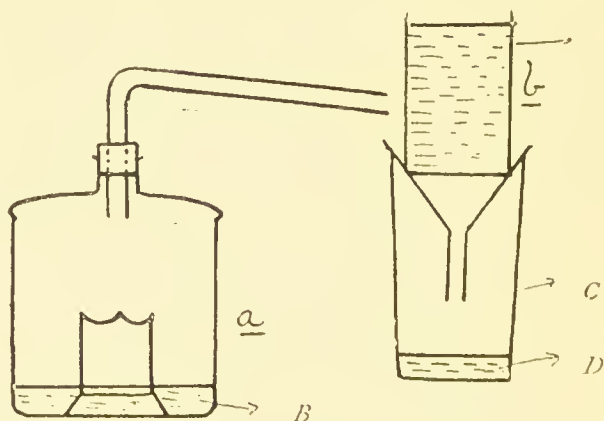


FIG. 7.—Apparatus for Boiling Milk and condensing the Steam from it.

a, b. Tins.

B. Milk.

C. Large Glass Vessel.

D. Colourless Liquid collected.

explanation has to be placed the fact that milk also "boils over" when the lid of the pan is kept on and where the skin is not formed. Also *water* boiled in a pan which has had milk boiled in it and has not been cleaned, "boils over" almost as badly as milk).

Fit up the apparatus shown in Fig. 7.

Expt. 6. Warm up the milk in the tin *a* containing the "cascade boiler" and allow the vapour which comes off to impinge on the vessel *b* containing cold water. Be careful to use a small flame, as even when using the "cascade boiler" there is a tendency for the milk to "froth up."

Water collects in the tumbler and *not* milk. **Milk** then is **not one distinct liquid, but something containing water**, and, judging from its specific gravity, a great amount of it. How much water?

It is well known that if a little water is left in a saucer exposed to the air of a room it slowly, apparently, disappears; and more quickly if the room is warm and dry. This apparent disappearing is called **evaporation**.

Expt. 7. Suppose we evaporate some milk, but, in order to save time, perform the evaporation by placing a known

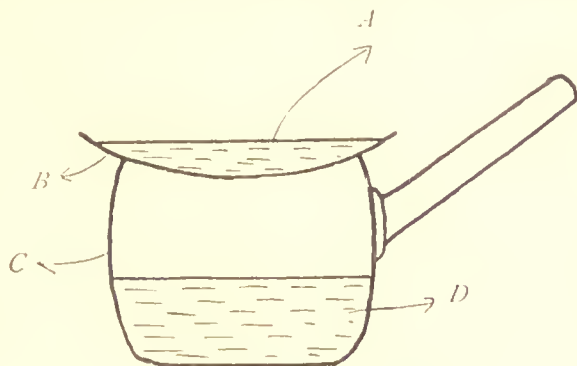


FIG. 8.—Evaporation of Milk.

A. Milk. *B.* Saucer. *C.* Saucepan. *D.* Boiling Water.

weight of it in a weighed saucer and placing on a pan of gently boiling water (see Fig. 8). In a few hours the milk will be left quite dry. One must not *guess* when this condition is reached. After some time take the saucer off the pan, dry the under surface, cool and weigh. Then place on the pan again, steam for another hour, and proceed as before, weighing after cooling. If two successive weighings agree one may safely conclude that all the water in the milk has been driven off.

What percentage loss has taken place, i.e., how much water is there and what percentage of material is left?

Example of experiment :—

	OZS.
Weight of empty saucer	$7\frac{3}{4}$
" " " " plus milk	$13\frac{1}{4}$
∴ the weight of milk taken is	$5\frac{1}{2}$
Weight of saucer plus dried milk	$8\frac{1}{2}$
(Two successive weighings agreeing.)	
∴ the weight of dried residue is	$\frac{3}{4}$
And the weight of water is	$4\frac{3}{4}$

Percentage of water = $\frac{4\frac{3}{4}}{5\frac{1}{2}} \times 100 = 86.4$, and, by difference, the percentage of solid material left is 13.6.

The dried residue from milk is called **Total Solids**, and its determination is a very important matter in milk analysis, as the addition of water to genuine milk lowers this percentage. Tap water yields no appreciable residue on evaporation.

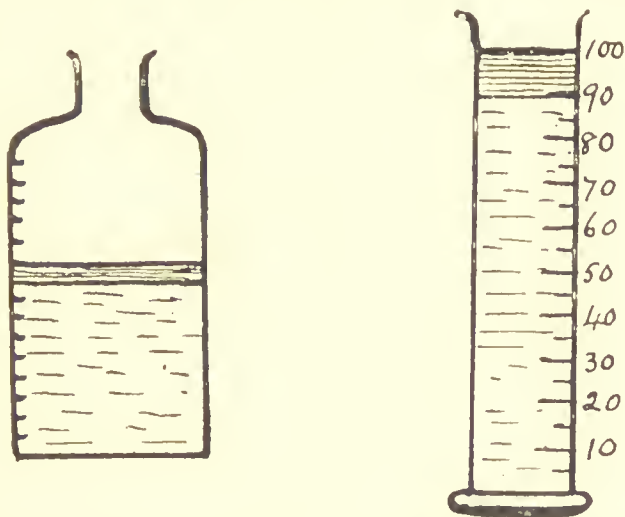
What is the nature of this solid residue in milk? Is it one substance or many?

As cream and skim milk are both obtained from milk, and these two are obviously different, it is clear that this solid residue *cannot* consist of *one* substance.

Before further examining the nature of the total solids, let us determine the amount of cream, and see if that also

affords an indirect means of determining the specific gravity of skim milk.

Expt. 8. Some milk is allowed to stand; the cream settles on the top and after about a day it is quite easy to see the whole of the cream, the line of separation, and the skim milk. If a medicine bottle be filled to the extent



1 Tablespoon of Cream from
10 Tablespoons of Milk in
Medicine Bottle.

12 Measures of Cream from
100 Measures of Milk in
Graduated Cylinder.

FIG. 9.

of, say, 10 tablespoons, it will be found that about 1 tablespoon, or division, is cream (see Fig. 9). If 100 measures of it are placed in a graduated cylinder (see Fig. 9), the percentage of cream can be read off at once after standing the requisite length of time.

Result of experiment :—

	Measures.
Volume of milk taken...	100
„ „ cream at the top ...	12
(i.e., 88 subtracted from 100).	
∴ the percentage of cream is ...	12

Cream is evidently lighter than skim milk as it separates on top of the latter. Is it lighter than milk or water?

Expt. 9. Carefully determine the specific gravity of some cream skimmed from the same kind of milk and not "clotted." Result of experiment:—

Weight of empty tea-cup	...	...	...	ozs.
"	"	"	full of cream	12
"	"	"	full of water	12
∴ the weight of either cream or water is				$8\frac{1}{2}$

Cream has then, bulk for bulk, the same weight as water, or its specific gravity is 1.

How can we now determine the specific gravity of skim milk by *calculation* and *not* by weighing?

In the 100 measures of milk we have 12 of cream which weigh 12. The 100 measures of milk weigh $100 \times 1.033 = 103.3$. The 12 measures of cream weigh $12 \times 1 = 12$. Therefore 88 of skim milk (*i.e.*, $100 - 12$) must weigh $103.3 - 12 = 91.3$, or 1 measure of skim milk weighs $\frac{91.3}{88} = 1.039$; *i.e.*, the specific gravity of skim milk is 1.039.

Suppose some of the specific gravities are grouped together:

Specific gravity of water	...	= 1
"	"	cream ... = 1*
"	"	milk ... = 1.033*
"	"	skim milk = 1.039*

**Be very careful to remember that cream, milk, and skim milk are not always of the same quality, and may, therefore, give different specific gravities with different samples used.*

Expt. 10. Evaporate to dryness a little cream in a saucer placed on a pan of boiling water. Repeat with a little skim milk in another saucer. Some solid is left in both cases, and the two residues, in correct proportions, together make up the total solids of milk.

Now we can easily follow what will happen if genuine milk is tampered with. The addition of water will lower the specific gravity and lessen the total solids, since tap water is lighter than milk and gives no appreciable solids. The removal of some cream will raise the specific gravity slightly but lower the amount of total solids, particularly the "cream solids." The removal of cream and addition of some water might make the specific gravity the same as that of genuine milk, but the amount of total solids will be too little both in the "cream solids" and in the "skim milk solids." *In testing milk* then it will now be seen that *reliance cannot be placed on the specific gravity alone*, as very poor milk, by unscrupulous juggling, may be made to give a specific gravity identical with that of genuine milk. The total solids will at once indicate any tampering. It is not likely that cream will be added to milk as an adulterant, but this will raise the percentage of solids, particularly cream solids, and slightly lower the specific gravity. The removal of cream and the addition of skim milk will make the specific gravity higher than that of genuine milk, but lower the "cream solids."

If the various points on specific gravity and solids left on evaporation have been clearly grasped, it will now be easy to work out a question such as the following: Milk of specific gravity 1.032 is diluted with water until the specific gravity is 1.027. What percentage of water has been added?

Suppose 100 measures of milk are taken. These will weigh 100×1.032 , as against 100×1 if water. 100 measures of milk weigh 103.2. Let the number of measures of water added to the 100 of milk be x . These will weigh x . We have now $100 + x$ measures of diluted milk, and these weigh $(100 + x) \times 1.027$.

$$\therefore 103.2 + x = (100 + x) \times 1.027$$

Weight of genuine milk and weight of water added =
weight of diluted milk.

$$103.2 + x = 102.7 + 1.027 x.$$

$$.027 x = .5$$

$$x = \frac{.5}{.027} = 18.5$$

i.e., 18.5 measures of water have been added to 100 of milk, or the percentage of added water = 18.5.

Nature of the "total solids" of milk.—We have seen that the solid residue from milk cannot be one substance. *How many substances does it contain?*

Expt. 11. Evaporate some cream in a saucer placed on a pan of boiling water. This may take many hours. The residue looks very oily when warm, and may be poured off into a dish, or a few drops on to a piece of paper. A grease spot is made in the latter case. The cold residue looks like pale butter.

Expt. 12. Heat a little of this in an iron spoon. It gives off a disagreeable odour of burning fat.

The solid matter in cream is **Fat**. Consequently milk contains **Fat**. Fat is one kind of food material, or food-stuff, and no diet is perfect if it be absent.

Expt. 13. Evaporate some skim milk *just* to dryness in a saucer, stirring from time to time in order to make the residue resemble white crumbs. Taste it. It is slightly sweet. What substance is sweet? Sugar. Is this residue *entirely* a sweet substance? If sugar, what does sugar dissolve in? Water.

Heat up the residue in a pan with a little boiling water for about five minutes, and then pass through a fine gauze sieve such as is in constant use in kitchens for straining coffee, etc. Some of the substance stays on the sieve. It cannot be "sugary" or it would have dissolved in the water. Evaporate the clear solution to dryness in a saucer and taste it. It is sweet, but *not so sweet as ordinary sugar*. It is a sugar, but **Milk sugar**, not cane sugar. Heat a

little in an iron spoon. It blackens and gives off fumes of burning sugar. Here then is another kind of food-stuff in milk; one which blackens on heating and evolves "burning sugar" fumes. This particular kind of food-stuff is known as **Carbohydrate**. **Milk contains carbohydrate.**

Examine now the residue in the gauze sieve. Taste it. It has no appreciable taste. Heat a little in an iron spoon. The substance blackens and gives off fumes resembling the smell of burning feathers. Here is another kind of food-stuff called **Protein**, or **flesh-forming material**. **Milk contains Protein.**

Expt. 14. Finally, take a little of the total solids, *i.e.*, the residue from whole milk, and strongly heat in an iron spoon on top of a red hot fire or over a gas ring. No matter how long the heating is carried on, some almost white substance remains in the spoon, which will not burn away, but glow while it is hot like a piece of lime. This is another kind of food-stuff, **Mineral salts**, or **Ash**. **Milk contains Mineral Salts.**

These are all the different kinds of food-stuffs which are essential, so that milk contains representatives of each, and is therefore a perfect food.

To sum up, milk contains largely water and some (about 13% altogether) fat, carbohydrate, protein, and mineral salts or ash.

The average composition of milk is—

				%	
Water	...	...	...	87.1	} 100
Total solids	...	...	...	12.9	

The "total solids" in milk are made up of (about)—

				%	
Fat	3.9	} 12.9
Milk sugar	4.75	
Protein	3.5	
Mineral salts or ash75	

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Or one pint of average milk contains approximately—

					OZS.
Water	18
Fat	$\frac{3}{4}$
Milk sugar	1
Protein	...	...	...	...	$\frac{3}{4}$
Mineral salts or ash	...	...	...	...	$\frac{1}{6}$

Infants and young children require very little solid in food, or solid food, so that for them, milk is practically as perfect in the amounts of its constituents, as it is in the nature of its constituents. For adult life, milk contains too little solid substance to be *alone* sufficient to support vigorous activity.

The specific gravity of milk is often referred to as 32, 31, 29, etc., the actual specific gravities being 1.032, 1.031, 1.029, etc., respectively. If any one of the former numbers is denoted by G and the total solids by T and the percentage of fat by F , we can say that

$$T = .25 G + 1.2 F + .14.$$

The following example illustrates the use of this formula:—

A sample of milk, of specific gravity 1.032, gave on analysis 13.1% of total solids. What is the percentage of fat in the milk? Substituting in the above expression—

$$\begin{aligned} T &= .25 G + 1.2 F + .14 \\ 13.1 &= .25 \times 32 + 1.2 \times F + .14 \\ 1.2 F &= 4.96 \\ F &= \frac{4.96}{1.2} = 4.13\% \text{ of fat.} \end{aligned}$$

If this percentage of fat is subtracted from the total solids the number 8.97% is obtained. This amount is called "**solids not fat.**" By law, genuine milk must be able to show *at least 3% of fat, and 8.5% of "solids not fat."* A prosecution invariably follows if analysis reveals lower figures in either case.

Milk and Disease.—It has been well established that many infectious diseases are transmitted by and through milk, so that all farmers must see that their shippens are kept as clean as possible, and that the milk is not allowed to stay in, or near them, or in any other possibly objectionable place. As milk is one of the most important and universal of foods, any contamination of it with disease, or impoverishment of the quality, is a very serious offence.

Milk contains a huge, minute, population, invisible to the naked eye, and may also acquire harmful germs from the surrounding air. One kind of invisible life in it causes the milk to turn sour after a time.

If fresh milk is boiled and cooled, or scalded and cooled, and this operation performed two or three times and then the milk kept in closed bottles away from the air, it keeps sweet much longer and is safer to drink. Milk treated in this way is said to be **Pasteurised**. Whenever there is doubt as to the purity of milk, or during an epidemic of infectious disease, the milk should be boiled or pasteurised and kept closed up from the air until required for use.

QUESTIONS.

1. Explain clearly what is meant by the terms density and specific gravity. Describe carefully how you would determine the specific gravity of (*a*) paraffin oil ; (*b*) turpentine ; (*c*) a solution of soap.

2. How would you prove experimentally that milk is not *one* liquid, and how would you determine the percentage of water in it ?

3. What is meant by the "total solids" of milk ? How would you determine (*a*) the percentage of total solids ; (*b*) the percentage of cream ; (*c*) the specific gravity of the skim milk, in a sample of milk ?

4. Describe experiments which show that the "total solid" of milk is not one substance. What different kinds of food-stuffs does it contain, and how would you demonstrate their presence ?

5. A sample of milk is found to have an average specific gravity, and yet to be deficient in "total solids" and cream. How is this explained ?

6. What would be the effect on the specific gravity of milk of (*a*) adding water ; (*b*) extracting cream ; (*c*) adding water and

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skim milk ; (*d*) extracting cream and adding water? How would the food value be altered by these operations?

7. A sample of genuine milk of specific gravity 1·031 was diluted with water until its specific gravity became 1·027. How much water had been added (*a*) per cent. ; (*b*) per gallon?

8. Why is it unwise to rely upon the specific gravity alone in testing a sample of milk?

9. A sample of milk has a specific gravity of 1·033 and gives 12·94% of "total solids." What is approximately the percentage of fat in it?

10. Some genuine milk shows 13·01% of "total solids" and 3·8% of fat. What is the specific gravity of it?

11. What is meant by "sterilisation" and "pasteurisation" of milk respectively, and how is each performed?

12. Why is the question of the purity of a milk supply of the greatest importance?

CHAPTER II

Percentage of solid matter in the beverages tea, coffee, and cocoa, and the nature in each case—The amounts of tannin in cheap and expensive teas, and the difference between these teas—Food value of these beverages—The percentage of solids in bread, cheese, vegetables, beef and fish, and their nature and food values—The object of food not merely to satisfy hunger.

THE densities and specific gravities of tea, coffee, and cocoa have already been determined. [If the specimens of these beverages have been kept, more experiments can be performed with them. If not, prepare some more.] It will be remembered that milk gave about 13% of solid material suitable for food, and this of excellent quality. *Do the beverages, tea, coffee and cocoa, contain as much solid material as milk?* If not, how much, and is it in each case valuable as food? Let us examine tea first.

Expt. 15. Weigh out, as carefully as possible, $\frac{1}{4}$ oz. of tea on a letter weigher able to indicate $\frac{1}{32}$ oz. (see Fig. 10), and then add it to one pint of boiling water, or pour the water on to the tea placed in a suitable vessel.

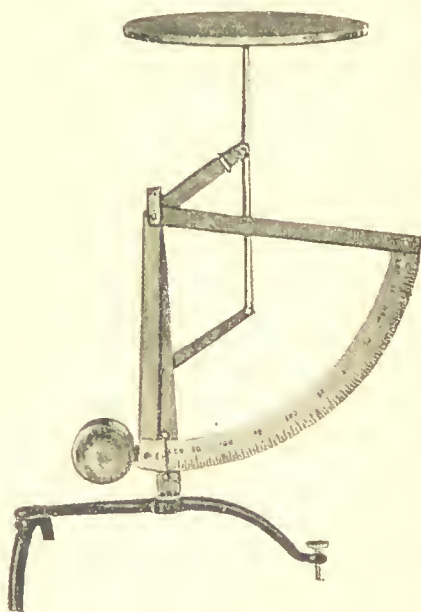


FIG. 10.—Letter Weigher.

Allow to stand for three or four minutes. Now strain off the tea, collect all the leaves, and dry them perfectly in a weighed saucer over a pan of gently boiling water. When thoroughly dry see how much tea is left.

Example of experiment :—

		oz.
Weight of piece of paper	... =	$\frac{1}{16}$
Weight of tea taken	... =	$\frac{1}{4}$
Weight of dry tea-leaves after tea had been made from it...	... =	$\frac{3}{16}$
∴ the weight of tea which had dissolved ... ..	... =	$\frac{1}{16}$
Percentage of tea which dissolved in the infusion	$= \frac{1 \times 4 \times 100}{16 \times 1} = 25.$	

In half-a-dozen experiments performed in this way the percentage varied from 12 to 25, but how much solid substance did the tea infusion contain approximately? One pint of water weighs about 20 ozs., and the weight of tea infusion would consequently be $20 + \frac{1}{16}$ oz., of which $\frac{1}{16}$ oz. is solid. The percentage = $\frac{1 \times 16 \times 100}{16 \times 321} = 31.$

Supposing for a moment that this solid substance in tea is, weight for weight, equally valuable for food as that contained in milk, there is so little of it that the food value is almost negligible.

Expt. 16. Perform a similar experiment with coffee. Are the dried coffee grounds so much less in weight than the original coffee to warrant the conclusion that a beverage has been obtained containing as much as, or more, than 13% of solids in the total weight of the fluid? If not, coffee cannot possibly have the food value that milk has. A somewhat different method is required for the cocoa.

Expt. 17. Weigh out $\frac{1}{4}$ oz. of cocoa on the letter weigher placed on a piece of paper previously weighed. Place

the cocoa in a cup and pour on half a pint of boiling water, stirring all the time. Allow to cool. When quite cold, weigh on the spring balance, not forgetting to subtract from the total weight that of the empty cup. The weight of cocoa drink is thus obtained. Suppose this equals $10\frac{1}{4}$ ozs. In this $10\frac{1}{4}$ ozs. we have $\frac{1}{4}$ oz. of solid cocoa (and even this may not be all solid), *i.e.*, we have $\frac{1}{4}$ oz. of solid in $10\frac{1}{4}$ ozs. of the beverage, or

$$\frac{1 \times \frac{1}{4} \times 100}{\frac{1}{4} \times 41} = 2.44\%$$

Cocoa taken as a beverage, then, does not contain so much solid substance as milk unless an excessive amount (about five times as much as in our experiment) is used for the purpose. Since milk solids are also perfect in their nature of constituents, half a pint of milk has more food value than half a pint of cocoa made with water. The addition of milk will, of course, improve the food value, and cocoa made entirely with whole milk will be better than milk alone.

What is the nature of the drinks—tea, coffee, and cocoa? Tea is yellowish-brown in colour, the exact tint depending upon the blend, the time of infusion, and the amount of leaves added; coffee is dark brown, sometimes nearly black; and cocoa is reddish. If the last is allowed to stand, a clear, slightly reddish-brown fluid separates from some solid which collects at the bottom of the vessel. No cocoa is *perfectly* soluble, notwithstanding the many advertisements to the contrary. It has already been determined that the amount of solid in the clear infusion of any of these drinks is very small, but evidently there is something in them, otherwise there would be no colour, aroma, or taste.

Expt. 18. Take a little of the cold tea and add a solution of ferric chloride or perchloride of iron. A bluish-black inky substance is obtained; in fact, it is practically

an ink. This is a test for **Tannin**. Repeat with the clear coffee and the cocoa. Almost similar results are obtained, and so *the presence of tannin in each is demonstrated*. The word *tannin* is unfortunately used in a casual and indefinite manner, and covers many different substances similarly constituted to the tea tannin.

Expt. 19. Add a little raw white of egg to some more tea and coffee. What happens? The transparent white is clotted or coagulated and becomes opaque and lumpy. Uncooked white of egg is much more easily digested than the cooked or coagulated.

Tea and coffee clot white of egg without any heating, so that they will retard the digestion of the latter if taken at the same time.

Expt. 20. Add a little fluid gelatine (made by adding some solid gelatine to warm water, and then cooling) to some tea. Coagulation takes place at once, and the clotted mass becomes brownish in colour from the pigment present in the tea and coffee. Again, the clotted form is not so readily attacked by the digestive juices as the unclotted, and since gelatine is often eaten either in the form of jellies, beef or otherwise, the combination with tea or coffee is an undesirable one. *Is there a simple method by which the tannin can be precipitated, i.e., removed in a solid form?*

Expt. 21. Prepare a very strong solution of salt in water by adding salt to some water until, after stirring, a solid excess collects at the bottom of the vessel. Allow to settle thoroughly, and then add a little of this clear salt solution to some of the cold tea, and stir. Flocks of a dirty white substance will be noticed floating about. These are the *tannin* which the salt has thrown out of solution. If the solution is passed through a piece of fine muslin placed on a sieve, the whole of it can be collected.

Some erroneous impressions are current with regard to

the amount of tannin in different samples of genuine tea. Of 18 specimens of black tea the maximum percentage of tannin was 9.142, the minimum 6.922, and the mean 8.1. Very astringent teas were found to contain as much as 39 to 42%, and one very choice Assam showed 33%. It is well known that tea and coffee in strict moderation act as stimulants. This effect is produced by the presence of a substance called **Theine**, in tea, and **Caffeine**, in coffee; but the two names denote the same substance.

What causes tea, coffee, and cocoa to have their characteristic odours and flavours? (Smell and taste are, of course, inseparably connected.)

Expt. 22. Take about 2 ozs. each of tea, coffee, and cocoa, and put in bottles provided with somewhat loosely fitting corks. Pour on each about 4 ozs. of ether, cork loosely, and leave in a very cool place away from any flame (see Fig. 11).

Shake cautiously from time to time with a rotary motion, but keep the bottle quite upright, and do **not** agitate by means of an up-and-down movement. After standing two or three days and shaking each, perhaps a dozen times in all, at regular intervals, carefully pour off each ethereal fluid into a flask and connect, by means of a cork with a hole bored through it, to an arrangement for condensing any ether vapour given off on heating (see Fig. 12).

A piece of cardboard rests on top of the pan containing water. A circular hole of requisite size in this cardboard allows the flask to rest on it securely. The long glass tube *a*—which, of course, must be supported suitably—fitted through a hole in the cork of the flask, is

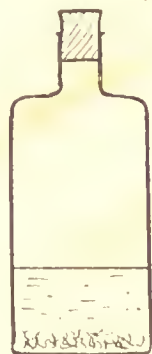


FIG. 11. — Ether poured on Tea, Coffee and Cocoa.

surrounded by a wider tube, nearly filled with cold water, and, at least, water-tight at the bottom end *c*. On boiling the water in the pan, the steam which is given off easily boils the ether in the flask, and the cold water arrangement converts this ether vapour into liquid ether, which collects in *b*. (A few small pieces of broken pot placed in the flask before being joined to the tube *a* will cause the boiling of the ethereal solution to be more regular.) The heating of the pan containing water must not be carried out on a fire, but by means of a gas ring and a very small light.

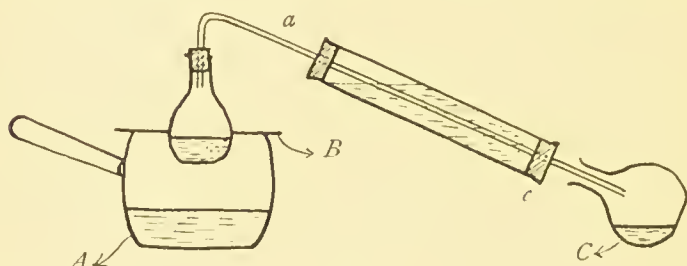


FIG. 12.

A. Pan containing gently boiling Water. *B.* Cardboard. *C.* Ether.

After some time, depending upon the amount of ether, the boiling ceases, and, in the case of the tea, a very small quantity of a citron-yellow fluid is left. Now stop the heating, disconnect, and place the flask on top of or near a warm oven, blowing inside the former through a piece of glass tube every five or ten minutes. After about half-an-hour no smell of ether will remain, but instead a very unmistakeable one of tea. *This citron-yellow fluid or oil is the substance which imparts to tea its characteristic odour and flavour.* An expensive tea is often one composed of carefully-picked leaves and possessing a fine aroma and flavour, due to the presence in it of more than the usual amount of this aromatic oil.

Expt. 23. Perform similar experiments with the ethereal fluids from the coffee and the cocoa. A dark, brownish

substance is left from the coffee, having a very strong smell of the berry, and, in the case of the cocoa, an almost white, buttery-looking substance, smelling like chocolate. *The odorous material in the first case, and the cocoa butter in the second, impart to coffee and cocoa respectively, their characteristic odours and tastes.*

Are ordinary tea, coffee, and cocoa *quite* dry substances? They certainly look dry.

Expt. 24. Take about $\frac{1}{4}$ lb. of each and place on dried, weighed saucers or tins, and steam on top of pans of boiling water for about 12 hours, or until they are constant in weight. (Always dry the under surface of the saucer and cool before weighing.) Is there now exactly $\frac{1}{4}$ lb. of each remaining? No; showing that although a substance may look quite dry, it may contain some water capable of being driven off on heating with steam.

Except in the case of cocoa, only the *clear* infusions are drunk, and since these liquids contain very little solid material, and that of a somewhat objectionable character, the food value can only be slight, even negligible. With cocoa, however, if a teaspoonful is used in making a cup of the beverage, the whole of it is allowed to remain. Consequently cocoa drink contains more substance than either tea or coffee.

Expt. 25. Heat a little solid cocoa in an iron spoon; copious fumes are evolved, and a piece of moistened red litmus paper held near these is turned blue. *This is an alternate method of testing for Protein.*

Expt. 26. Boil up some cocoa with water, pass through a piece of muslin on a sieve, and allow to cool. If a little cold solution of Iodine is now added (obtained by dissolving a little Iodine in boiling water and cooling) a deep blue colour is obtained, indicating the presence of **Starch**, another example of a **Carbohydrate**. With most cocoas, small oily globules may be noticed floating about when they are made

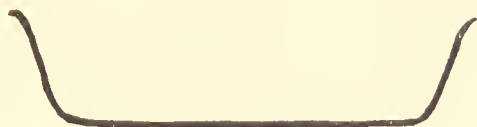
up with boiling water. *These are molten fat. Cocoa contains fat then.* There is also a stimulating substance present, very similar to that in tea and coffee. This is called **Theobromine**. Weight for weight, cocoa is 'a much more valuable food than milk; but whereas a person might easily drink 1 lb. of milk at a meal, he would be quite unable to consume 1 lb. of cocoa. In judging the food value of cocoa, this fact must be constantly borne in mind. Again, some people find that even a small quantity of cocoa disagrees with them, so that to such individuals cocoa has no food value. Below are given a few figures relative to these beverages (full analyses are not given):—

Tea (solid).			%	Coffee (solid).			%
Water	...	...	11.5	Water	...	...	10
Theine	...	...	1.35	Caffeine	...	...	1.4
Ethereal Oil	...	...	.67	Aromatic Oil	...	...	10
Tannin	...	...	12.36	Fat	...	...	15 to 20
Woody Fibre	...	...	20.3	Tannin	...	...	19 „ 23
Ash	...	...	5.1				
Cocoa (solid).							%
Water	...	...	...	...	...	...	6
Cocoa Butter	...	...	...	...	...	...	50
Theobromine	...	...	...	...	...	...	1.5
Starch	...	...	...	...	...	...	10
Protein	...	...	...	...	...	...	18
Ash	...	...	...	...	...	...	3.6

All these figures must be regarded as *average ones*, each different sample analysed being almost certain to give varying proportions of the ingredients.

Percentage of Solids in Foods.—Before one can gauge the value of a food, *it is necessary to find out how much water there is in it; or better still, the amount of solid substance.* Although water is essential to life, it is impossible to live on it alone for an indefinite length of

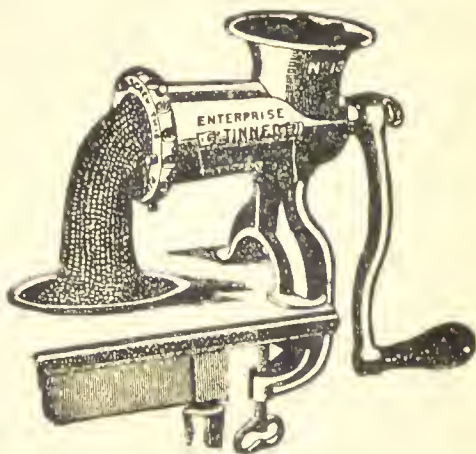
time; so that for our purpose we must reject from the valuation all water present in food. As was proved by Expt. 24, a substance appearing quite dry may contain water, and lose it on being heated. It is impossible, for example, to *see* that washing soda contains about



Section of Tin used for drying Foods.



Mincer.



Mincer.

FIG. 13.

63% of water. Taking an extreme example, for the sake of illustration, let us suppose that a food at 6*d.* per lb. contained 1% of solids. (Many fruits contain only about 5%.) What would this imply? That practically nothing but water was being bought at 6*d.* per lb. The value of the determination of the solid substance in foods is therefore obvious. The foods suggested for

experiment are bread, cheese, cabbage, turnip, potato, beef, and fish (cod).

Expt. 27. Weigh out as carefully as possible each of the foods, in a finely divided condition, preferably minced by being passed through a mincer (see Fig. 13), and place each in a weighed circular shallow tin (see Fig. 13).

Now steam them on pans of boiling water for a few days (*i.e.*, for perhaps 30 hours actual time altogether) until their weights are constant. *What amount of material is now left in each case, and what percentage is it?*

Examples of experiments:—

Bread.

	ozs.	
Weight of tin	$= 2\frac{3}{4}$	$\left\{ \begin{array}{l} \therefore \text{ the weight of} \\ \text{bread taken} = 4\frac{3}{4} \\ \text{ozs.} \end{array} \right.$
" " + bread	$= 7\frac{1}{2}$	
" " + dried		
bread	$= 5\frac{3}{4}$	
\therefore the weight of solid ...	$= 3$	
And percentage of solid	$= \frac{3}{4\frac{3}{4}} \times 100 = 63.2^*$	

Cheese.

	ozs.	
Weight of tin	$= 2\frac{3}{4}$	$\left\{ \begin{array}{l} \therefore \text{ the weight of} \\ \text{cheese taken for} \\ \text{experiment} = 5\frac{1}{4} \\ \text{ozs.} \end{array} \right.$
" " + cheese	$= 8$	
" " + dried		
cheese	$= 7$	
\therefore the weight of solid ...	$= 4\frac{1}{4}$	
And percentage of solid	$= \frac{4\frac{1}{4}}{5\frac{1}{4}} \times 100 = 81.^*$	

* Note carefully that bread, and cheese, are not substances of exactly constant composition, new specimens, weight for weight, containing less solid than stale.

Cabbage.

ozs.

$$\begin{array}{lcl}
 \text{Weight of tin ...} & = & 2\frac{3}{4} \\
 \text{" " + minced} & & \\
 \text{cabbage...} & = & 8\frac{3}{4} \\
 \text{" " + dried} & & \\
 \text{cabbage ...} & = & 3\frac{1}{2} \\
 \therefore \text{the weight of solid ...} & = & \frac{3}{4} \\
 \text{And percentage of solid} & = & \frac{\frac{3}{4}}{6} \times 100 = 12.5.
 \end{array}
 \left. \begin{array}{l} \\ \\ \\ \\ \\ \end{array} \right\} \begin{array}{l} \therefore \text{the weight of} \\ \text{cabbage taken for} \\ \text{experiment} = 6 \\ \text{ozs.} \end{array}$$

Turnip.

$$\begin{array}{lcl}
 \text{Weight of tin ...} & = & 2\frac{3}{4} \\
 \text{" " + turnip} & = & 8 \\
 \text{" " + dried} & & \\
 \text{turnip ...} & = & 3\frac{1}{2} \\
 \therefore \text{the weight of solid ...} & = & \frac{3}{4} \\
 \text{And percentage of solid} & = & \frac{\frac{3}{4}}{5\frac{1}{4}} \times 100 = 14.4.
 \end{array}
 \left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\} \begin{array}{l} \therefore \text{the weight of} \\ \text{turnip taken for} \\ \text{experiment} = 5\frac{1}{4} \\ \text{ozs.} \end{array}$$

Potato.

$$\begin{array}{lcl}
 \text{Weight of tin ...} & = & 2\frac{3}{4} \\
 \text{" " + potato} & = & 8\frac{3}{4} \\
 \text{" " + dried} & & \\
 \text{potato...} & = & 4 \\
 \therefore \text{the weight of solid ...} & = & 1\frac{1}{4} \\
 \text{And percentage of solid} & = & \frac{1\frac{1}{4}}{6} \times 100 = 21.
 \end{array}
 \left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\} \begin{array}{l} \therefore \text{the weight of} \\ \text{potato taken for} \\ \text{experiment} = 6 \\ \text{ozs.} \end{array}$$

Beef.

$$\begin{array}{rcl}
 & \text{ozs.} & \left\{ \begin{array}{l} \therefore \text{the weight of} \\ \text{beef taken for} \\ \text{experiment} = 5\frac{1}{2} \\ \text{ozs.} \end{array} \right. \\
 \text{Weight of tin ...} & = 3 & \\
 \text{" " + beef...} & = 8\frac{1}{2} & \\
 \text{" " + dried} & & \\
 \text{beef ...} & = 4\frac{1}{2} & \\
 \therefore \text{weight of dried} & & \\
 \text{beef ...} & = 1\frac{1}{2} & \\
 \text{And percentage of solid} & = \frac{1\frac{1}{2}}{5\frac{1}{2}} \times 100 = 27\cdot3. &
 \end{array}$$

Fish.

$$\begin{array}{rcl}
 & \text{ozs.} & \left\{ \begin{array}{l} * \therefore \text{the weight of} \\ \text{cod used for ex-} \\ \text{periment} = 6\frac{1}{4} \\ \text{ozs.} \end{array} \right. \\
 \text{Weight of tin ...} & = 2\frac{3}{4} & \\
 \text{" " + cod ...} & = 9 & \\
 \text{" " + dried} & & \\
 \text{cod ...} & = 3\frac{3}{4} & \\
 \therefore \text{the weight of dried} & & \\
 \text{cod ...} & = 1 & \\
 \text{And percentage of solid} & = \frac{1}{6\frac{1}{4}} \times 100 = 16. &
 \end{array}$$

* The fish contained no skin or bone.

Grouped together, the percentages of solid matter are as follows :—

Bread ...	63·2	Potato ...	21
Cheese ...	81	Beef ...	27·3
Cabbage ...	12·5	Fish ...	16
Turnip ...	14·4		

N.B.—These figures are the results of experiments carried out by one individual. The pupil should perform similar experiments and accept the numbers thus obtained so long as they are not very different from these. In no case should the specimen weighings and results be copied.

Although these figures, as such, are of great importance, it will be of very little use, and far from correct, to place them in descending order and then assume that the food values descend correspondingly. Why? *The solids are very different in nature and composition. The one food-stuff which is absolutely indispensable is Protein.* If this is absent, or present in only small quantity, the food value is modified in the light of that fact. Moreover, some foods contain quite a lot of woody fibre, which is practically paper. This has no food value. Some consideration of these factors and their modification of food values will be briefly considered later. *The object of food is not merely to satisfy hunger.*

Many medical officers of health and medical inspectors of schools for industrial towns frequently call attention in their reports to the fact that an all too great number of the children are ill-nourished. Except in a few cases there is no allegation of neglect against the parents, or even an implication of it, but rather of a lack of knowledge of food values and the requirements of growing children—the future men and women. It is a pity that a little of the energy often wasted in social and educational directions is not devoted to work on this vital matter. It may perhaps, be urged that something is being done at the present time—supplying breakfasts for school children, for example. But this is not educating the children or their parents to understand their mistakes in feeding and to know how and what to eat. At present there is too much bread and tea and too little oat food eaten. It is not suggested that more expense should be incurred, perhaps less.

The author was approached at the suggestion of the schools' medical officer of an industrial town in the north of England, with regard to simple experimental means of demonstrating that correct feeding is not merely satisfying hunger, but something more. He was asked, "*How would you demonstrate to children that there is more*

nutriment in 1 lb. of bread than in 1 lb. of boiled turnip? "

We have equal weights of ordinary food, but have we equal weights of dry or solid food value material? What has been found?—for bread 63·2% solids. The figure for boiled turnip has not yet been obtained. Here is an example of the experiment. A turnip was boiled in the usual manner until cooked. It was then passed through the mincer, some of it weighed in a tin, and then dried over steam, as in the case of the other foods.

		ozs.	
Weight of tin was...	...	3	} ∴ the weight of boiled turnip taken was 5½ ozs. (As nearly as could be weighed.)
" " + boiled turnip was		8½	
" " + dried boiled turnip was		3½	
∴ the weight of dried residue was	...	½	
And percentage of solid was		$\frac{\frac{1}{2}}{5\frac{1}{2}} \times 100$	= 9.

It will thus be seen that the amount of solid in bread is about 7 times that in boiled turnip, and it is scarcely likely that the 9% in the latter will be of such superior quality as to counterbalance the much higher percentage in bread. But suppose we do not take this for granted. How can the question be settled by demonstration?

Expt. 28. Heat a little of the dry bread in an iron spoon. It blackens and gives off burning-feather fumes fairly easily. *Protein is present in appreciable amount.*

Expt. 29. Take a little more of the bread, warm up with water, cool, and add a little of the iodine solution previously made. A blue colour is obtained. *Starch is present, i.e., some carbohydrate.*

Expt. 30. Take some of the dried turnip and heat in the spoon. Plenty of fumes are evolved that smell like burning straw, or paper and sugar mixed, thus indicating that *protein is practically absent*. The dried turnip is certainly sweet, *i.e., it contains a sugar*; but this is almost the only food material in it. About one-half of the solid is indigestible woody fibre.

Another ready method of judging the value of the solid residue is to see how much of it will dissolve in water—about as warm as the body. If a large proportion dissolves (and this will be readily noticed) an equally large amount is immediately available and useful as food.

Expt. 31. Take a little of the dried food, add warm water, then a little **Pepsin** (obtained from a chemist; ask for Parke-Davis pepsin), **glycerine**, and a few drops of **hydrochloric acid** or “spirit of salt.” In this manner the gastric juice of the stomach is crudely imitated. Allow the test to proceed for a few hours keeping the mixture “body warm” all the time. Notice how much solid passes into solution.

Viewing now the problem of feeding as a whole, it is suggested that children be shown that equal weights of different foods yield very different weights of actual solid food. This to be followed by an examination of the nature of the solid as indicated by (a) the nature of the fumes evolved on heating and the ease with which they are given off; (b) the amount soluble in warm water, or imitation gastric juice; and (c) the amount of insoluble substance left from (b) and which, on being heated, evolves fumes smelling like burning paper. One must be careful not to confuse this smell with that of burning feathers, for, in many cases, there will be a protein residue from the dried food, insoluble in water and perhaps some even after the “imitation stomach juice” has operated.

Experiment on food values seems to show that while the

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forces of nature operate continually for good, our ideas of nurture are often in direct antagonism. Education, mainly through food value demonstrations, ought in course of time to alter this.

QUESTIONS.

1. How would you determine the percentage of solid material in infusions of (a) tea ; (b) coffee ?

2. 1 pint of boiling water is poured on to 1 oz. of ground coffee for the preparation of coffee infusion. It is then found by experiment that 30% of it has dissolved. What is the percentage of solid substance in the coffee infusion, and how would you experimentally verify your calculated result ?

3. Discuss the relative food values of (a) milk ; (b) cocoa ; and (c) tea.

4. What simple experiments would you perform to indicate the natures of coffee and cocoa, both in the solid and beverage conditions ?

5. A sample of cocoa is provided. Describe carefully how you would determine the percentage of cocoa butter in it.

6. Why is the determination of the amount of solid in a food of the greatest importance ? A 2 lb. loaf costing 3*d.* has 60% of solids in it ; another of similar quality costing 3½*d.* has 70% of solids in it ; which is really the cheaper of the two ?

7. Describe carefully how you would determine the percentage of solid material in (a) lean beef ; (b) potato ; (c) raw cabbage.

8. Samples of four different foods are supplied. Describe in detail how you would endeavour to determine their relative food values.

9. How would you demonstrate the superior quality and quantity of nutriment in 1 lb. of cheese to that in 1 lb. of raw carrot ?

10. How many different kinds of food-stuffs are there, and how would you demonstrate in a simple manner some of their properties ?

CHAPTER III

The difference between heat and temperature—Baking and roasting of meat ; Good and bad methods—Loss in weight on baking, the nature of the loss, and the changes the meat undergoes.

THE words "heat" and "temperature" are frequently and erroneously used as synonyms, *i.e.*, of similar meaning. The expression "*heat of the oven*" is often met with, and this, in its real meaning, is far different from what is usually intended. There is little objection to referring to the oven as being a "*quick*," "*moderate*," or "*slow*" one, because almost everyone means and understands by these terms a *hot*, a *fairly hot*, and a *moderately warm* oven respectively. Before directly discussing the question of heat and temperature, and the difference in meaning between the two, it will be instructive to examine one or two analogies. Suppose we have two purses containing money ; purse "a" contains one penny and purse "b" one sovereign. To say that they hold money is merely to mention the presence of that commodity, and although they each contain one coin, the value in purse "b" is 240 times that in purse "a." Again, let us suppose that two purses, "a" and "b," each contain a pound sterling, but "a" contains 240 pence and "b" one coin in gold—a sovereign. Although both purses are equal in value, the currency or monetary *level* of any one coin in "a" is much lower than that of the single one in "b." Let us now consider what is known as the *water analogy*.

Expt. 32. Two glass vessels of very different diameters are connected at the bottom by means of a glass tube, in the centre of which is a glass tap so arranged that com-

munication may be established or broken off between the two vessels at will (see Fig. 14).

Call the larger vessel "a" and the other "b." A little cochineal or other colouring matter is added to some water to impart a colour to it, and a little of this poured into "a" (the tap being turned on) until the level of water in the two vessels is about 2 ins. above the tap. *The two heights of water are the same.* Now turn the tap off and then on. *There is no movement of the water.* Turn off

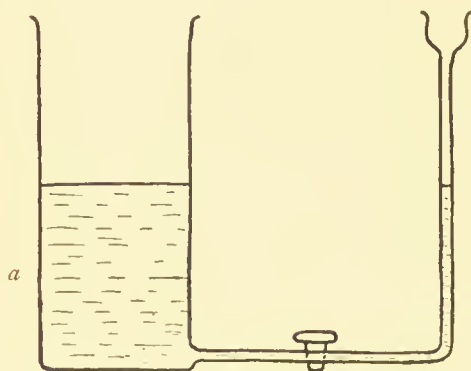


FIG. 14.—Two Glass Vessels communicating with a Tap between.

the tap again. Pour a little more of the water into the narrower vessel until the level is about 2 ins. above that in the bigger one. Open the tap. What happens? *The level of the water in "b" falls until once more the two levels are the same.* Turn the tap off and pour some

more of the coloured water into "a" until the level here is about 2 ins. above that in "b." Turn the tap on. The level of the water sinks in "a" until those in "a" and "b" are the same. *What determines the flow of the water? Difference of level alone, the absolute amount of water having nothing to do with the movement.* Now leave this matter of the flow of water for a few moments.

Expt. 33. Place an ounce weight and a pound weight, attached to cotton thread and string respectively, into boiling water contained in a tin, and continue to boil for about ten minutes with the thread and string hanging out so that the weights may be lifted out at any time. *Will the*

two become equally hot? Would they burn the finger equally, if they were touched by the finger tip? Could anyone with closed eyes tell from the burning sensation experienced, whether the ounce or the pound weight had been touched? The answer to the first two queries is in the affirmative, and to the last in the negative. What will melt paraffin wax or ice? Warmth, heat—anything hot.

If the two weights are equally hot, is this the same as saying that they hold or contain the same amount of heat? After the weights have been in the boiling water for the

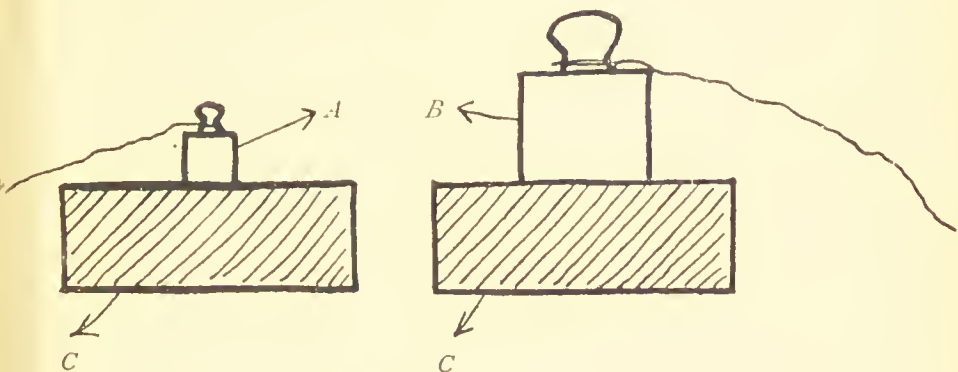


FIG. 15.—1 oz. and 1 lb. Weights placed hot on Slabs of Paraffin Wax.

A. Ounce Weight. B. Pound Weight. C. Slab of Paraffin Wax.

length of time suggested, take them out quickly by means of the thread and string attachments, and, at once place them simultaneously on separate slabs of paraffin wax (see Fig. 15).

The wax at once commences to melt in both cases, as the heat that the weights contain is imparted to the wax. When both have cooled down it will at once be noticed that the large weight has melted more wax than the small one. *Since heat is required to melt wax it follows that the pound weight contained more heat than the ounce weight. Although equally hot, the amounts of heat were different.* Imagine now that the weights are proportionately

magnified into 1 cwt. and 16 cwts. How would this affect the result of the experiment? Would the ratio of wax melted be different to the ratio with the proportionately smaller weights? Not in the least. Suppose these different weights of metal were made into ovens and heated as before, would this in itself affect the amount of wax melted? No. Would the oven made of 16 cwts. of metal cook anything better than the small one, if both were equally hot? No. It would merely be able to cook a larger article. The two equally hot ovens are at the same *temperature*, or *level of heat*, but the larger one contains more heat, as evidenced by the greater quantity of wax melted.

How is heat measured? *Firstly*, the amount of material of the substance must be known, *i.e.*, its weight. *Secondly*, its capacity for heat. A dozen different people weighing, say 140 lbs. each, will, in all likelihood, have a dozen different capacities for walking, running, jumping, eating, thinking, or what else you will. Just as there is unequal capacity for anything in almost everything one can mention, so different substances of the same weight have different capacities for heat; *i.e.*, greatly different amounts of heat will have to be imparted to equal masses before they become equally hot; or, conversely, very different amounts of heat will be given out, weight for weight, on cooling equally. *Thirdly*, the alteration of level of heat, or difference of **temperature** must be known. The fact that a stone will fall from a height, if released, is independent of its weight or the distance it falls; but any damage done *is* dependent upon these. This distance or height then is an important factor in measuring the damage done by a falling stone; and the fall of temperature is correspondingly necessary in gauging the heat given out on the cooling of a body. *In fact the amount of heat given out on cooling, or received on heating, is equal to the quantity of material or mass of the body \times its capacity for*

heat \times *the change of level of heat or temperature*. The almost analogous factors in the case of the damage caused by the falling stone would be the mass of it, the degree of hardness or softness, and the distance fallen.

Reverting now to the flow of water in the two glass vessels, this flow is analogous to the passage of heat when two bodies at different temperatures are brought into communication with each other, and is quite independent of the mass of water, just as the mere falling of the stone has nothing to do with its weight. The water *at the same level* in the two unequal size vessels corresponds to the two unequal size ovens *at the same temperature*. There is no flow of water in the first case on establishing communication, and no passage of heat in the second. The water at the higher level in vessel "b," is analogous to the small oven hotter, *i.e.*, at a higher temperature, than the larger one; and just as water flows in one case, so heat flows in the other, although the *amount* of water or heat is much less in the smaller vessel or the smaller oven respectively. Lastly, the water at higher level in "a" corresponds to the big oven at a higher temperature or level of heat than the smaller one; and just as water flows from high level to low, so heat flows from something at a high temperature to another at a low temperature. **Temperature is level, or degree of heat, and when the heat of the oven is referred to, the temperature or degree or level of heat is really meant.** Heat is *not* a substance but a *form of energy*, and temperature is the intensity or level of it.

How may the temperature of an oven or a room be measured? You see clearly what is required to be done. Just as one might measure the depth of water in a tank by means of a stick or yard rule (no idea of the *amount* of water being gained thereby), so we can measure the level of heat (paying no regard to the quantity). **An instrument which enables temperature to be determined is called a Thermometer.** It is generally mounted on a wooden or

metal frame, for the sake of convenience, but whatever form it takes it is always the same in principle (Fig. 16). The thermometer is made of glass and is perfectly closed to the air. One end is a bulb communicating with a thin tube—perhaps not quite as wide as a pin—extending the whole length of the instrument. The bulb, and a portion of

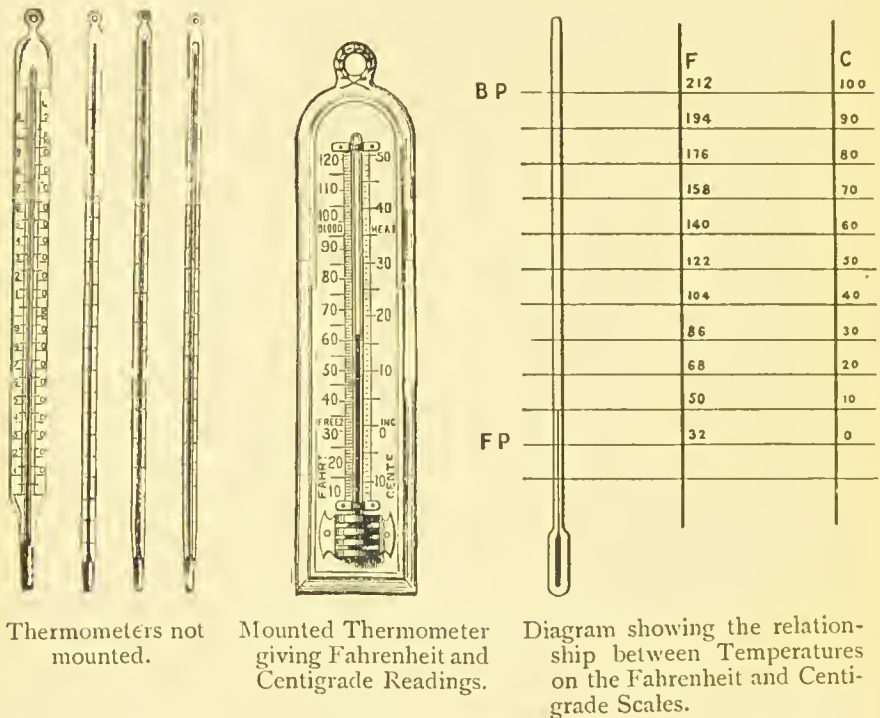


FIG. 16.

the stem, are filled with mercury or quicksilver, the exact amount of the stem filled depending upon the temperature of the medium in contact with the thermometer. The part of the stem not containing mercury is an empty space—no air, no mercury, nothing—*i.e.* vacuum. When the thermometer is placed in a warm substance the quicksilver expands, and the only way it can do so is by moving up the stem until it is at the same temperature as the

surrounding substance; the expansion then ceases. In contact with something colder a shrinkage occurs, and the thread of mercury in the stem falls until all contraction ceases. Numbers and marks are etched, printed or stamped, on the glass or frame, and the temperature is obtained by noticing the reading on the same horizontal level as the top of the thread of mercury. There are two kinds of thermometers in common use, the only difference between them being in the relative value of the divisions, or numbers, or degrees, as they are called. On a **Fahrenheit** thermometer the level to which the mercury sinks when placed in melting ice is labelled 32° (the small circle denotes degrees); on the **Centigrade** thermometer 0° . The level to which the mercury rises when placed in steam, is marked 212° and 100° respectively. "F." and "C." denote "Fahrenheit" and "Centigrade" thermometers. Consequently 100° C. are equal to $212^{\circ} - 32^{\circ}$ F. = 180° F.;

or 5° C. = 9° F., or 1° C. = $1\frac{4}{5}$ or $\frac{9}{5}$ F., and 1° F. = $\frac{5}{9}$ C.

Very often the kind of thermometer is not mentioned in speaking of the temperature of a room or oven, *e.g.*, "The temperature of the room is 60° ." Unless one is referring to a Turkish bath, Fahrenheit is inferred. In pure science the Centigrade is almost invariably employed, but in ordinary life and in domestic science the use of the Fahrenheit thermometer is equally general. To convert temperature on one scale to temperature on the other, the simplest rule is first of all to add 40 to the number, then multiply by $\frac{5}{9}$ if the conversion is from F. to C., or $\frac{9}{5}$ if from C. to F., and finally subtract 40 from the result.

Examples :

(1) Convert 65° F. to $^{\circ}$ C. Add 40 = 105. Multiply

$$\text{by } \frac{5}{9} = \frac{105 \times 5}{9} = \frac{525}{9} = 57\cdot2. \quad \text{Subtract 40} \\ = 17\cdot2^{\circ} \text{ C.}$$

(2) Convert 23° C. to $^{\circ}$ F. Add $40 = 63$. Multiply by

$$\frac{9}{5} = \frac{63 \times 9}{5} = \frac{567}{5} = 113.4. \quad \text{Subtract } 40 = 73.4^{\circ} \text{ F.}$$

Baking and Roasting.—These are often supposed to be the same operation. Baking implies cooking with the oven practically closed so that only a little air is admitted. In roasting, the object is hung in front of a fire by means of a “spit,” which either slowly rotates or permits of such a motion as to expose all surfaces equally to the fire.

Expt. 34. Examine a little raw meat under a microscope (only a very thin section or slice must be used); the fibres of meat will be noticed fastened together by an almost colourless substance known as elastin. Bear in mind how wild animals, such as the lion and tiger, have to tear their food because it is eaten raw.

The reasons for baking or roasting meat are many: (1) To improve the flavour; (2) to render the meat more palatable and digestible; (3) to avoid any shock to the æsthetic sense which would be felt if raw meat were taken; and (4) to destroy anything of an objectionable nature which might be in or about it.

We shall now apply experimental methods to the comparison of baking and roasting, and not merely accept expressions of opinion. Experience, to be of value, should be the result of methodical experiment. Household cookery has been severely hindered by lack of scientific method and go-as-you-please working.

In baking meat in the oven, one of two principal courses may be adopted: (1) To place the meat in a cold oven and gradually heat up, or, (2) to place in a hot oven and maintain it so. Whichever of these two methods is found to be the better, the question remains, how hot must the oven be both at the beginning and end of the cooking? Before we can start examining the two ways of baking, it

is necessary that the *maximum degree of heating required be determined.*

Expt. 35. Secure a rather large circular tin provided with a lid. Bore two small holes through this lid, and one

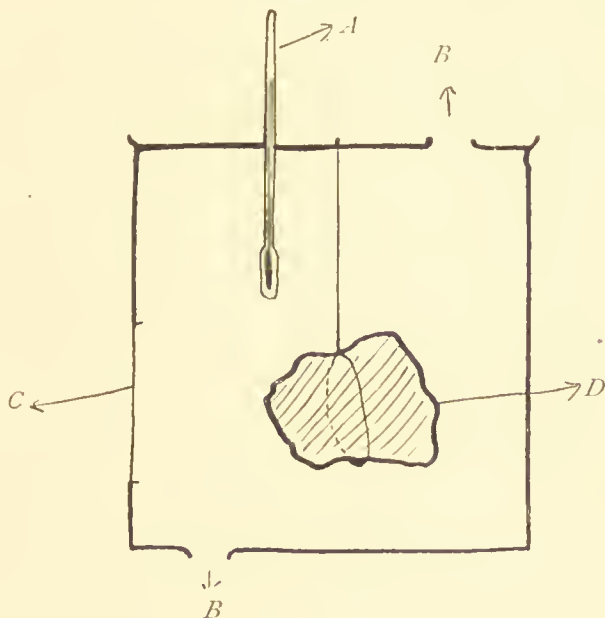


FIG. 17.—Apparatus for heating Meat in a Tin and viewing through a Mica Window.

A. Thermometer. *B.* Hole. *C.* Mica Window. *D.* Meat.

through the bottom of the can. A Fahrenheit thermometer (unmounted) is passed through one hole in the lid and firmly fixed by the aid of a little asbestos fibre inserted round the place where it meets the lid (see Fig. 17).

Take a piece of meat, say $\frac{1}{2}$ lb., put a hook through it, and attach the latter to some rather thick iron wire. Bore a small hole through the lid so as to allow the wire to pass through, and then secure it by wrapping round the tin, so that the meat will hang almost in the centre when the lid

is placed in position. If a hole is now made through the side of the tin, and this covered with sheet mica and fixed, one will be able to see how the meat changes as the heating proceeds. Start heating the arrangement on a ring burner, noting the temperature and watching the meat

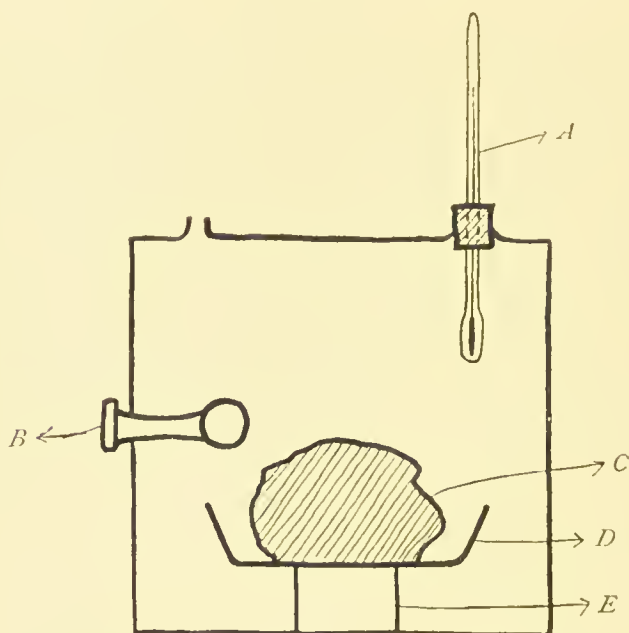


FIG. 18.—Small Oven for Baking Trials.

A. Thermometer. *B.* Oven Handle. *C.* Meat. *D.* Tin.
E. Earthenware Support.

through the mica window. The surface of the meat will be exposed to the same temperature as that of the heated air in the tin, and the thermometer will indicate this temperature. Continue the heating a little longer until the first sign of charring or blackening is observed, and again read the thermometer. Perfectly roasted or baked meat is, of course, never charred at any part, and in actual cooking the meat must not be raised to the temperature attained in the latter

part of the experiment. The highest temperature required will be found to be from 370° to 380° F. or 188° to 193° C., charring commencing at about 430° F. or 261° C.

For the trial bakings a small oven is desirable (see Fig. 18), provided with a thermometer so that the temperature can be read off and the heating regulated accordingly.

If an ordinary oven has to be used, the experiment may be performed—approximately—and the operations regulated in the usual manner by opening the door and seeing how the cooking is proceeding.

Expt. 36. (1) Weigh about 1 lb. of meat (lean beef), place in a weighed tin, and put in the cold oven. Now heat up to the maximum temperature required (this taking about twenty minutes) and maintain hot until properly baked. Take out of the oven, cool, and weigh. Has there been any alteration in weight?

Example of experiment :—

	lbs. ozs.	ozs.
Weight of tin	= 3	
„ „ + beef	= 1 0 $\frac{3}{4}$	
\therefore the weight of beef taken... ..	= 13 $\frac{3}{4}$	
Weight of tin + baked beef after cooling... ..	= 13	
\therefore the weight of baked beef	= 10 and loss = 3 $\frac{3}{4}$	
Percentage loss on baking	= $\frac{3\frac{3}{4}}{13\frac{3}{4}} \times 100 = 27\cdot3$.	

Expt. 37. (2) Hot oven to start with.

	lbs. ozs.
Weight of tin	= 2 $\frac{3}{4}$
„ „ + beef	= 1 2 $\frac{3}{4}$
\therefore the weight of beef taken... ..	= 1 c

	OZS.	OZS.
Weight of tin + baked beef		
after cooling... .. =	14	
∴ the weight of baked		
beef =	14	and loss = $4\frac{3}{4}$
Percentage loss on baking ... =	$\frac{4\frac{3}{4}}{16} \times 100 = 29\cdot7$	

The two specimens were about equally well baked and the loss in weight sustained by them was almost the same. The specimen from the oven cold at starting, was slightly dry on the surface, and did not seem so appetising as the other. Many cooks would be dreadfully shocked if one suggested placing meat in an oven cold to start with, but the experiment shows that, although an oven hot at the beginning is better than one cold, the results are not so superior as is generally thought.

Expt. 38. Similar experiments may now be performed with mutton, veal, and any other kind of meat. It is to be hoped that nobody will think these experiments a waste of food; the specimens are never so bad as to be unfit for consumption. On the contrary, it is recommended that they be eaten in the usual way for meals before a definite opinion is expressed. When one is convinced which is the best method to adopt in any particular case, the need for experimenting ceases. Future domestic cooking will then be repetition of that best method.

Expt. 39. Cut a thin slice or section of the cooked meat and examine under a microscope to find out whether there is any visible change.

Expt. 40. Take a little more and pick it apart or shred it with the fingers. This is more easily performed than with the raw meat, showing that the binding or connecting substance has considerably lost its adhesive property. We are now aware of the change (*a*) in appearance, (*b*) in taste,

(c) in colour, (d) in texture, (e) in odour,¹ and (f) of the loss in weight on baking. *Logically, the next problem is to find out something about the nature of the loss.* Does it really mean that from 25% to 30% of solid food is lost? Or is this largely water driven off by the heating? Obviously we must endeavour to collect the products given

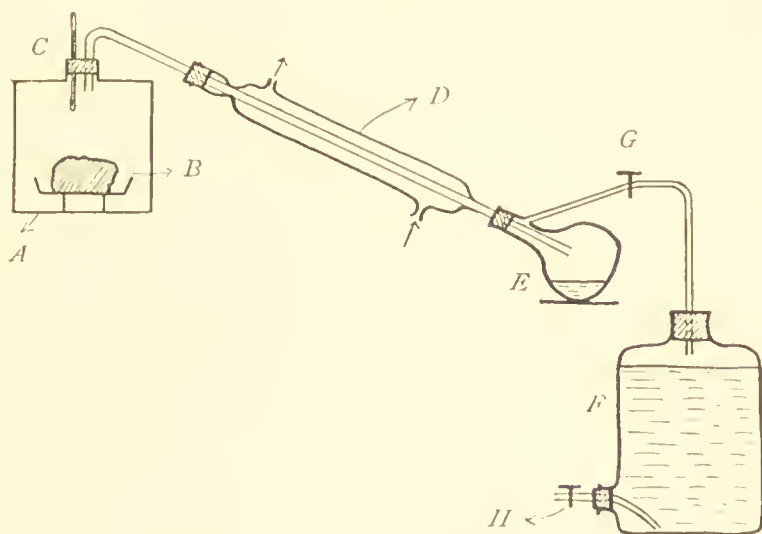


FIG. 19.—Apparatus for Baking Meat and collecting the volatile Products.

- | | |
|------------------------|-----------------------------|
| A. Tin Vessel. | E. Flask. |
| B. Meat. | F. Bottle. |
| C. Thermometer. | G. Screw Clip. |
| D. Liebig's Condenser. | H. To Sink or empty Bucket. |

off and examine them. The following apparatus has been devised for this purpose (see Fig. 19).

Expt. 41. A is the tin vessel which was used for boiling milk; B the weighed meat in a tin and resting on some earthenware support placed at the bottom of A; C a thermometer; D a Liebig's condenser described in Chap. IX.;

¹ The peculiar appetising odour of baking or roasting meat is due to a volatile substance to which the name Osmazome has been assigned.

E a small flask fitted to it in a gas-tight manner; G a screw clip so that the indiarubber tube may be closed, opened, or partially so; and F a big bottle filled with water provided with a tap at the bottom so that this liquid may be allowed to run out at any desired speed. The whole apparatus is gas-tight.

On heating the tin A with a ring burner, the meat is baked (observe the temperature by the thermometer). As soon as the baking is started, open the tap at the bottom of F to allow the water to run out slowly to a sink or suitable receptacle. This flow slowly draws out all fumes and vapours from the meat tin. The products, which are capable of being cooled to a liquid form, collect in the flask E, and the gaseous emanations pass into the big bottle F. If this latter is about $\frac{1}{2}$ cu. ft., or 25 pints capacity, the meat (weighing about 2 lbs.) will be cooked by the time all the water has run out, the operation taking about one hour. Quite a lot of liquid collects in E, and, of course, the bottle F is full of gas. Now turn out the light, screw up the clip G quite tightly, and disconnect at that place. Light a taper, take the cork out of F, and plunge the taper in. *It is at once extinguished*, and a few breaths of the gas are quite sufficient to cause headache. One advantage of roasting is now obvious, as these fumes are drawn up the chimney. There is, however, no suggestion that they in any way pollute the meat. *What is the liquid in E?* Disconnect and pour it out. It has a very distinct smell¹ of the baked meat, but otherwise resembles water. Since we have already found beef to contain about 70% of water (*vide* Chap. II.), and this liquid resembles water, we are quite justified in concluding it is that fluid. *The loss in weight, then, is made up largely of water, a gas which causes headache and puts out a light, and a substance which gives rise to the roast meat odour.*

¹ Osmazome.

We can now see more clearly what takes place on baking or roasting meat. The high temperature of the oven clots or coagulates that protein portion of the meat which is soluble in cold water (the albumen), but is not sufficiently high to char it (*vide* our experiment). The pores of the meat are thus closed, and the juices tend to be retained. When the oven is cold at the commencement, much water is driven off the surface of the meat before the albumen coagulates, and this tends to make that surface dry. The smaller the joint the higher must be the temperature that the surface is initially exposed to. *Basting* checks evaporation of the water, because a somewhat impervious oily layer is thus formed round the meat, and the water cannot escape quite so readily. The connective tissue in the meat is converted into gelatine, and thus the fibres are more easily separated, *i.e.*, the meat is more readily chewed and is more tender. If there is a fair amount of fat, and the oven too hot or too "quick," very disagreeable fumes of burning fat are evolved—fumes which are very familiar. Experiments were performed first with English beef and mutton, then with "frozen" or "chilled" beef. The frozen beef was found to contain slightly more water than English beef (76·8% as against 72·7%), and, on baking, it lost in one case 32% of its weight, and in another 38%, showing that for some reason, chilled beef more easily loses water, and does not give so heavy a cooked joint as English beef, equal weights being started with. If this is always the case, English beef might really be quite as cheap as Colonial, if not cheaper. Experimental methods of inquiry in cookery are surely justified in such questions, since they are of practical as well as scientific value.

QUESTIONS.

1. Explain clearly the difference between heat and temperature. What is the water analogy?

D.S.

E

2. Two substances a and b each weighing 1 lb. are heated to 100° C., and then allowed to cool, a to 20° C. and b to 10° C. Their relative capacities for heat are a , 1 and b , 2. What are the relative amounts of heat given out?

3. Criticise the following statements :—(a) the heat of the oven is 300° ; (b) the temperature of the room is less than that of the adjacent one.

4. 8 ozs. of a metal heated to 50° C. are placed on a slab of paraffin wax and on cooling melt 1 oz. of it. 6 ozs. of another metal heated to 70° C. melt $\frac{3}{4}$ ozs. of wax. What are the relative capacities for heat of the two solids?

5. Describe a thermometer; what is it used for? The requisite temperature of the oven for baking something is 300° F. What is this in degrees C?

6. Convert— 20° C. to $^{\circ}$ F., 15° F. to $^{\circ}$ C., and 120° C. to $^{\circ}$ F.

7. Describe the operations of baking and roasting, pointing out the difference between the two. What are the principal objects in baking meat?

8. A piece of beef is supplied. How would you experimentally determine the temperature required (a) to ensure efficient browning of the surface; (b) to *just* char or blacken that surface?

9. Which is the best method of baking a joint of meat? Give a full explanation of the advantages of your method.

10. How would you determine (a) the percentage loss on baking meat; (b) examine the nature of that loss?

11. Enumerate and describe the most important differences which you have been able to detect between raw and baked meat.

12. In providing a meal for 60 persons, $\frac{1}{4}$ lb. of roasted meat is allowed per head. The joint bought contains 15% of bone. How much of it approximately will have to be roasted, so that nothing but bone is left?

CHAPTER IV

“Boiling of Meat”; an examination of the various methods good and bad—Microscopical examination of raw and “boiled” meat; beef tea; beef jelly; extract of meat—Stock, bone and meat—The amount of animal and mineral matter in bone.

WHEN water is heated, the temperature rises until the water begins to boil. A thermometer placed in it then registers about¹ 212° F. or 100° C. The water may be allowed to boil gently or vigorously, but in either case *the thread of mercury remains at the same level for any particular sample of water and at any one period of time.* Great agitation of the surface of the water, or very active boiling, will require a larger fire or hotter flame than for gentle boiling, so that in such cases there is waste of fuel. *Violently bubbling water is no hotter than gently boiling or simmering water.*

Suppose we first examine the phrase, “*Boiling of meat,*” purposely put within quotation marks to indicate that although it is a frequently used stereotyped expression, it is not quite accurate. If meat were really boiled, it would imply that its juices were heated until they were actually agitated as water is when boiled. Roasting or baking meat approximates more to real boiling, as the juices are made much hotter than in boiling. So-called “*boiling of meat*” means cooking meat by means of, or in, boiling water. Science has proved and demonstrated that water containing something dissolved in it, boils at a higher temperature than the *pure* liquid. Meat juice is practically water containing certain dissolved substances, and to boil it would require heating to higher than 212° F.

¹ The temperature of boiling water varies under certain conditions.

Expt. 42. Try to boil water by means of boiling water, *i.e.*, place a tin containing cold water into a pan of boiling water and see if that in the tin will ever boil. It never will. Much less then can boiling water boil the juices of meat, or boil the meat. Boiling water can only *cook* meat, and to distinguish this food from the *baked* or *roasted*, it is said to be *boiled*.

Before passing on to our experimental treatment of the subject, we refer to *simmering*. **Simmering** is gentle boiling, *i.e.*, cooking by means of gently boiling water, and in the great majority of cases is quite as effective in cooking as vigorously boiling. The mechanical agitation of a piece of meat induced by the "walloping" of energetically boiling water may tend to disrupt the fibres more than simmering water; but that can be the only possible advantage and a somewhat meagre one to set against the decided disadvantage of waste of fuel consequent upon vigorous ebullition. *Many people call cooking by hot water and not boiling water "simmering."* This is a misuse of the term.

If meat is cooked for eating, as in the case of roast meat, *i.e.*, for itself alone, we must endeavour to retain all the "good" of the meat, or as much of it as possible, and not knowingly permit it to pass into the cooking water.

In comparing methods of boiling let us follow similar methods to those adopted in connection with baking. Suppose we try (1) placing a weighed piece of lean beef in cold water and then heating up to boiling, maintaining that condition for about five minutes, and then finishing at a temperature of 140° to 160° F., and (2) placing the weighed lean beef in boiling water first and then cooking with the water not boiling, but between the temperatures mentioned in (1). How are we to judge between the two methods? Mainly by observing (a) the weight lost by the meat; (b) the relative flavour, appearance, and general "appetisability" of the two; and (c) the

amount of food material which has passed into the water.

Expt. 43. Example of (1):—

Weight of meat taken = 12 ozs.

This was put into cold water, heated up to boiling, kept boiling for five minutes, and then finished off at 150° F. (another 45 minutes). The meat was then taken out, cooled, and weighed.

				ozs.
Weight of boiled beef	...	...	=	8 $\frac{3}{4}$
∴ the loss in weight	...	...	=	3 $\frac{1}{4}$
and percentage loss	...	...	=	27·1

The water in which the meat had been placed, was kept.

Expt. 44. Example of (2):—

Weight of meat taken... .. = 13 ozs.

This was put into boiling water, boiled for five minutes, and then finished off at 140° to 160° F., until cooked (an additional 45 minutes). The meat was then taken out, cooled, and weighed.

				ozs.
Weight of cold boiled beef	...	...	=	10 $\frac{1}{3}$
∴ the loss in weight	...	...	=	2 $\frac{2}{3}$
and percentage loss	...	...	=	20·5

The amount of water used was proportionately the same in both experiments. Although there was a quite appreciable difference in the losses of weight, acceptance of these figures, without due consideration of the other factors, would be faulty judgment; *e.g., how do we know that these percentage losses are not water only?* For, provided equal weights of beef were taken, there would still be the same nutriment or food in the two specimens. An examination of the water used, revealed some more information. In that from the first experiment there was much more solid

substance floating about than in that from the second. What was this? A certain portion of meat dissolves in cold water, but not in boiling (because the latter coagulates it). This is **Albumen**, an important part of the meat, and a valuable food. Without any actual weighing then, it can be seen that more nutriment had been removed from the meat in the first experiment than in the second. Consequently, specimen (1) could not be so rich in food as specimen (2).

Expt. 45. If a little more definite information be desired, take the water in each case and evaporate to dryness in a weighed saucer over a pan of boiling water. This will be tedious, as far as length of time required is concerned, but quite easy to do. Which leaves the larger residue? *That liquid will contain more food, to the complemental impoverishment of the boiled beef.* If, however, the water used is reserved for making stock, the objection of loss of food disappears. With regard to general appearance and flavour, the meat is better in the first experiment, but it would require a delicate palate to discover *much* difference in flavour. On the whole, it will be agreed that it is desirable in boiling meat to place it in boiling water first, in order to coagulate the albumen and thus stop as much as possible the extraction of soluble material. A microscopical examination of the meats is interesting, if only for comparison with the raw and baked meats, but brings out nothing of particular value.

Beef Tea.—In the preparation of this stimulant the object is to extract from the beef *all*, or *almost all*, the material soluble in water. Complete removal of the soluble constituents is impossible, as will be explained later. Many are at a loss to explain the great amount of extraction which takes place on putting minced raw meat into cold water, and leaving without stirring. The explanation of this spontaneous extraction involves some excellent physical science. (*N.B. Expt. 46 is difficult to perform*).

Expt. 46. Take a porous pot or cell, such as is used in electric batteries; fill it with a solution of copper sulphate or blue vitriol, allow it to soak through, and then pour it out. A solution of potassium ferrocyanide is now poured in; a brownish deposit is obtained, permeating the vessel. This pot is now filled with water, fitted with a rubber stopper, with one hole through it, and then a glass tube fitted through this latter, as shown in the figure (see Fig. 20).

The bend of the tube contains mercury, at the same horizontal level in the two limbs. If the cell is now placed in a weak solution of sugar, the level of mercury in limb *b* becomes gradually depressed and elevated in *a*, showing that there is less pressure exerted in the pot than before. *This is due to*

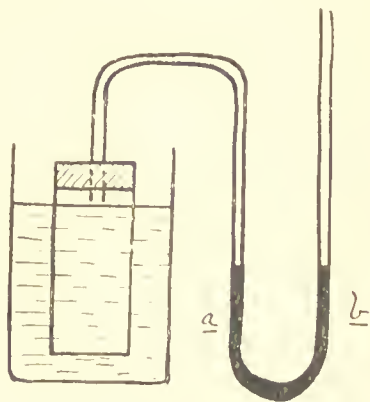


FIG. 20. — Apparatus to show Osmotic Pressure.

the outgoing of water, owing to the presence of the dissolved sugar in the vessel surrounding the pot. If, however, the pot holds sugar solution stronger than that surrounding it, water passes into the cell and the level of mercury in *a* is lowered and raised in *b*. This passage of water *only*, due to difference of concentration of solution, or a solution and the pure solvent, is called **Osmosis**, and the pressure exerted thereby **Osmotic pressure**. Suppose we further consider the question, using *plant cells*. If some of these cells are placed in water they slowly swell up and eventually burst. If, however, they are placed in a solution of salts (*e.g.*, common salt), stronger than that of the cell juice, they slowly flatten and collapse. In the first case, where the cells swell up and burst, the cell juice is a solution of substances, and the water surrounding is not, so

that water passes into the cells—that is, in the direction of the solution, but does not pass out. None of the dissolved salts are concerned in the passage—merely the water. When the cells are placed in the salt solution stronger than that constituting the cell juice, they collapse, as already stated, because, here again, the water *only* passes from a weaker solution to one stronger, *i.e.*, from the cell outwards. Hence the collapse of the cells. The cell walls are said to be a *semi-permeable* membrane, *i.e.*, they allow only the water or solvent, but not the dissolved substance or solute to pass through. This passage of solvent only, in one direction—one way or the other—is called **Osmosis**, and the pressure caused by it, as manifested by the change in the plant cells, is called **Osmotic pressure**.

Expt. 47. Prepare a solution of common salt (which is heavier than water), and fill a ground flanged glass jar with it, covering with a greased ground-glass plate. Then take another cylinder the same size, but open at both ends and with greased ground flanges, and fill with water by putting a

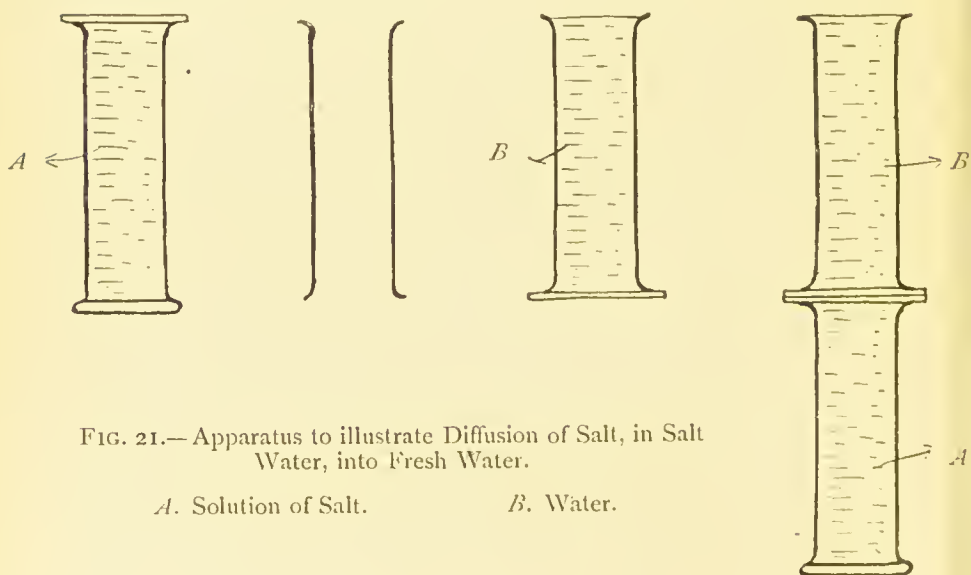


FIG. 21.—Apparatus to illustrate Diffusion of Salt, in Salt Water, into Fresh Water.

ground greased glass cover over one end so as to close it in a water-tight manner. Now place this water on the top of the solution of salt so that the two glass plates are superimposed. We thus have a solution of salt, and water separated by two glass plates (see Fig. 21).

Now very carefully slide away the two plates so as to establish communication between the jars. There seems to be no reason why the water in the top cylinder should become at all salty, as the heavy salty water is below, the lighter water above, and there is no shaking of any kind. Allow the two to remain in position for a few hours. Then draw off a little fluid by means of a glass tube from the middle of the jar which originally contained the fresh water. Taste it; it is quite salty. In time,¹ the water in the two cylinders would become equally salty, *i.e.*, the bottom one would lose and the top one gain salt. **The spontaneous passage of dissolved substance is called Diffusion.** The regulation of the circulation of sap in trees and plants, and the derivation of plant food from the soil are the result of osmotic pressure and diffusion.

How are osmotic pressure and diffusion concerned in the extraction of substance from minced beef by still cold water? The beef contains substances in its juice, and these are partly dissolved in the fibres and partly between them. The water surrounding the meat contains none of these. Water consequently passes into the meat fibres, causing them to swell—a phenomenon often observed—by osmotic pressure, and at the same time the second phenomenon of diffusion takes place because of the passage of dissolved substances from the meat into the water. The meat fibres are not *perfectly* semi-permeable. When the solution of substances in the water is as strong as the gradually diminishing strength of solution in the meat juice, passage of water *alone* stops, *i.e.*, osmosis ceases, and so also does the diffusion. If the solution surrounding *did* tend to become

¹ Perhaps months: the salt diffuses *very* slowly.

stronger than that in the meat juice, what would happen? Water would pass out of the meat into the surrounding solution, making it weaker. What would happen then? Osmosis in the other direction and diffusion again. Equilibrium is established when the two solutions of substances, *i.e.*, the one remaining in the meat, and the other surrounding it, are exactly alike in concentration. It will thus be clearly seen, that it is impossible to extract the whole of the soluble material from meat in this way, even using fresh lots of water again and again, to surround the meat.

The preparation of **beef tea** is usually carried out as follows :—

Expt. 48. Mince some beef steak and surround with cold water, equal weights of each being taken, and allow the mixture to stand for an hour or two. If carried out in a stone jar, it is then best to surround with boiling water placed in a pan, and finish off with hot water, so that the beef and fluid are heated to between 140° and 160° F. An ordinary porringer is excellent for the purpose. Many strain off all the scum, which quickly forms after the heating is started. This is a mistake, and a concession to clarity, at the expense of value; for it is the coagulated albumen which the cold water had previously dissolved out. The clear strained beef tea contains substances called **kreatine**, **kreatinine**, **lactic acid**, and soluble salts, and these make the tea stimulating, rather than nutritious. No digestion has to be performed before they pass into the blood stream. Hence it is that in cases of prostration a cup of beef tea has an almost immediately revivifying effect. The very insipid residue left after straining off the beef tea is *alone* practically valueless as food, due almost entirely to this insipidity. But, if taken in conjunction with the beef tea, the whole of the nutriment of the beef is re-constituted. The two together form good food, but either alone is deficient; the tea is too stimulating, and the other too nauseatingly insipid.

Extract of Beef.—There are many thick, dark, reddish-brown products on the markets sold under various names, but all come under the heading “Extract of Beef.” Preparation of similar articles on a small scale is difficult, and as difficult to describe clearly enough for others to imitate. The mere concentration of beef tea (already described) by evaporation does not give these viscous, highly beefy-flavoured products. It has been found best to bake a lump of beef at a high temperature—somewhat higher than the usual one required—and then extract the reddish-brown juice by pressure. This is then mixed with a sufficiency of salt and evaporated in a hot oven until it becomes pasty. Such beef extracts consist of the soluble substances already mentioned, but in a highly-concentrated form, and fail somewhat because they are too largely stimulating, though, of course, exceedingly useful. To remedy this defect somewhat I took the meat residue, the insipid substance, dried thoroughly, and then reduced it to fine powder. It then became a pale buff-coloured material. Some of this was added to the stimulating extract, and became thereby, in my opinion, much more valuable as a food. On making into the tea form by the addition of water, this powder floated about or settled at the bottom of the vessel when left undisturbed. Bovril contains a perceptible powder. Can this be the same as, or similar to, the one obtained by pulverisation of the dried meat residue?

Beef Jelly.—This is somewhat similar to Brand's Essence. In order to obtain the beef product in a jelly form, it is necessary to have *gelatine*, and this is readily derived from the gristle which forms quite a visible part of shin beef.

Expt. 49. Shin beef is minced, covered with cold water, left for two hours, and then heated by hot water to about 140° to 150° F. for another three hours. The whole is then strained until it appears as a slightly yellow clear

fluid, and salt is added. If equal parts by weight of beef and water are used the extract will, as a rule, set to a jelly without further concentration. The setting of the jelly requires time as well as cooling, a thicker jelly being obtained after two days' standing than after one day. The addition of a little caramel (made by heating sugar to 410° F. for some time) to impart a reddish-brown, roast-beefy colour may, by its mere colour, act as a stimulus to the appetite, and increase the relish of the product. The addition of the trace of caramel does not, of course, appreciably alter the taste.

Stewing of Meat.—After what has been said with regard to the preparation of beef tea, little need be said on the question of stewing, so long as what is exactly required is

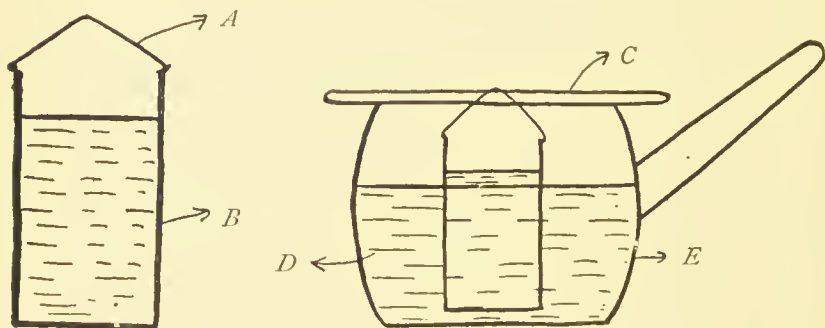


FIG. 22.—Simple Device for Stewing Meat.

A. String. *B.* Jam Jar. *C.* Piece of Wood. *D.* Boiling Water.
E. Saucepan.

thoroughly borne in mind. By many, the boiling of meat and the preparation of stew are carried out on similar lines, except that in the latter the meat is cut in small pieces. This is a mistake. In boiling meat the object is to retain as much nutriment in the meat as possible; but in stewing the aim is to extract the nutriment, and eat the meat with it. A stew should have good, rich gravy, and this cannot

possibly be obtained by following the same method as in boiling meat. Diffusion and osmosis are concerned in the preparation of the gravy portion of the stew, and as a somewhat high temperature favours these two actions, it is best to have the stew made with hot, but not boiling, water. Boiling water would coagulate the albumen, and boiling of the meat would then take place. A temperature of 140° to 160° F. is best obtained by heating in a double pan or porringer, as already mentioned. This temperature changes the albumen into a condition similar to that of the white in a lightly boiled egg. The whole stew should be both appetising and nourishing. The heating in the double pan might be carried on for four hours. For those who have no porringer a very useful and cheap substitute is made by suspending a jam jar (with a loop of string attached to it) from a piece of wood placed across the top of the pan containing the boiling water (see Fig. 22).

Stock, Bone and Meat.—The preparations of bone and meat stocks lend themselves to some useful and interesting experiments. In all stocks the object is to make something directly nourishing, and with no decided flavour; so that any kind of soup can be prepared from them by the addition of the characteristic and individual substances or their essences. With bone stock, the following treatment is suggested.

Expt. 50. Take 1 lb. of bone and 1 lb. to $1\frac{1}{2}$ lbs. of water and heat up (maintaining the level of water in the jar or pot by additions from time to time) until the bones appear porous. Now take out the bones, carefully allow anything which drains off to fall into the stock pot used, allow to dry in the air, and weigh. Do the bones weigh as much as they did before? If not—and they can scarcely do so since we have prepared the stock from them—what is the actual and also the percentage

loss? Next examine the stock. Measure the volume of it, and evaporate an aliquot part, say $\frac{1}{3}$ or $\frac{1}{4}$, to dryness in a weighed saucer. Thus determine the amount of the solid material in the whole of the stock by simple multiplication of this weight by the requisite figure. Now add the weight of dried stock to that of the bones left. What is the total?

Expt. 51. Similar experiments could be carried out with meat stock, and with a combined meat and bone stock.

The Amount of Mineral and Animal Matter in Bone.—If a portion of a leg bone is scraped quite clean, and the marrow emptied out, it looks as if we have one substance, just as we assuredly have one bone. *Is there in reality one substance?* Almost everybody is aware of the fact that such a bone placed on a hot fire soon bursts into flame. At once we have a means of finding out whether the bone is one substance. If the bone starts burning on the fire and is *one* substance, surely the whole of it will burn. Does this happen? The burning ceases long before the whole of the bone has disappeared, and a very brittle almost white substance is left, obtained by a gradual crumbling of the heated bone. The fire may be an exceedingly hot one, but, nevertheless, this remains and will never burn. *Thus there are at least two different substances in the constitution of bone, (a) one which burns away, and (b) one which does not.* This latter is called **Mineral matter**. How may its amount be determined?

Expt. 52. Weigh a rather large cleanly scraped bone, place it on an iron tray of such a size that it will rest conveniently on the fire. Leave there till all burning and blackening has ceased and an almost white substance is left. Remove the tray with a pair of tongs, allow to cool, then collect all the pieces of mineral matter and

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weigh them. What is the weight, and also its percentage of the whole bone?

Example of experiment :—

	ozs.	
Weight of bone taken	... .. =	$9\frac{1}{4}$
„ mineral matter left after		
heating	... .. =	5
∴ the percentage of mineral		
matter	... .. =	$\frac{5}{9\frac{1}{4}} \times 100 = 54$.

If there is 54% of mineral matter in bone, there must be, by difference, 46% of substance which burns away. This latter material is called **Animal or Organic matter**. Instead of determining the amount of this indirectly by subtraction, suppose we endeavour to estimate it by direct experiment. Obviously we have now to take a certain weight of bone, remove the mineral matter, and leave the animal matter. A solution of hydrochloric acid or spirit of salt of the strength 1 volume of strong acid to 6 volumes of water is able to slowly dissolve out the mineral ingredients, but not the animal matter. This latter is consequently left, and in such a form that the shape of the bone is retained.

Expt. 53. Carefully clean another bone, from the same leg of beef, if possible. Weigh it, and then steep in the solution of hydrochloric acid.

A good quantity of acid should be used, perhaps equal to about 10 parts to 1 of bone. Instead of using all the acid at once, it is best to divide it into 3 equal portions, soaking the bone in each for a week. After this time, take out the bone. It will now be quite pliable and capable of being bent in almost any direction. Squeeze thoroughly to remove the acid permeated through it; dry it without heating, and weigh.

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Example of experiment :—

					OZS.
Weight of bone taken	=	11	
„ animal matter left after					
soaking three weeks in acid and					
subsequent drying with a cloth	...	=	5½		
∴ the percentage of animal					
matter	...	...	...	=	$\frac{5\frac{1}{2}}{11} \times 100 = 50.$

This 50% added to the 54% of mineral matter obtained in *Expt.* 52 gives 104%, an error of only 4% in the two results.

In the preparation of stock where bones form part or the whole of the food material, quite a good deal of the animal matter is boiled out, as gelatine, leaving the mineral matter. Many concentrated stocks on cooling and standing set to a jelly. The use of bones for stock-making is an example of the utilisation of something occasionally regarded as waste and thrown away. Conservation, and the prevention of waste in everything, should, as far as possible, be aimed at in domestic science as it is in modern chemical manufacture.

QUESTIONS.

1. In what different sense is the word “boiling” used in the two expressions (a) boiling water ; (b) boiling meat ?
2. You are required to find out the best method of boiling a piece of meat. Explain exactly how you would proceed.
3. By what experiment or experiments would you prove that “simmering” water is quite as hot as vigorously boiling water ?
4. What differences have you been able to notice between raw and boiled beef (a) by the naked eye ; (b) by the aid of a microscope ?
5. Explain clearly what is meant by the terms “osmosis” and “diffusion.” How are these two phenomena concerned with domestic science ?
6. Describe the preparation of (a) beef tea ; (b) clear, almost colourless beef jelly ; (c) roast beef-coloured, beef jelly ; and (d) extract of beef. Of what do these products chiefly consist ?

7. You are required to utilise the whole of some lean meat to make beef tea suitable for an invalid. How would you do this?

8. What are the main points of difference in treatment between (a) the boiling of meat ; (b) the stewing of it ?

9. What facts have to be borne in mind in the preparation of stock ?

10. Describe the experiments you have performed or would perform to show the changes to (a) the bone ; (b) the water, in the preparation of bone stock.

11. What is meant by animal and mineral matter in bone ? Describe exactly how you would determine their respective amounts?

12. A joint of meat weighing 5 lbs. has 18% of bone in it. The mineral matter in the meat itself is 5%. What is, approximately, the total percentage of mineral matter in the joint ?

CHAPTER V

Boiling and frying of fish, potatoes and vegetables—The changes they undergo, the losses they sustain, and the nature of those losses.

AFTER the rather full consideration of the phrase, "boiling of meat," in the last chapter, it need scarcely be said that the same objections hold with regard to the "boiling of fish and vegetables." Again, *conservation of food material and flavour must be our object.* In order to have

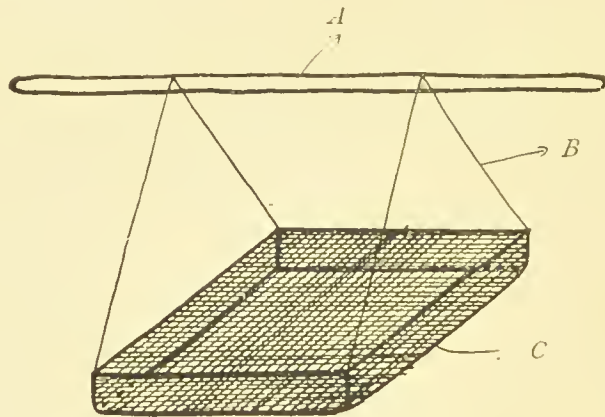


FIG. 23.—Wire Gauze Platform for Boiling and Frying Experiments.

A. Piece of Wood. B. Iron Wire. C. Wire Gauze Platform.

the various substances in the following boiling experiments self-contained, a piece of iron wire gauze, about 5 ins. square, was bent up at the edges so as to form a kind of perforated tray, and the four top edges were then fastened to iron wire and these attached to a piece of wood. The arrangement was then immersed in the boiling water, the

exact depth being obtained by varying the length of the supporting wires (see Fig. 23).

The article was always placed on this gauze platform, and the whole lifted out after cooking. Very rapid draining resulted and equally quick cooling to the temperature of the air.

Experiment with Cod.—

Expt. 54. Weigh a steak of cod, place it on the weighed gauze platform, immerse in boiling water in a rather tall

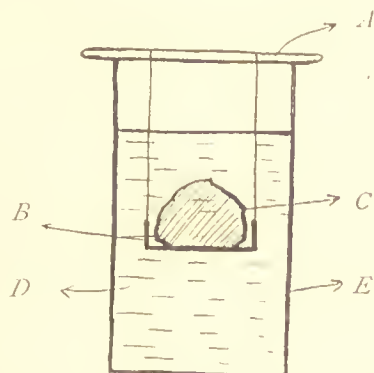


FIG. 24.—Apparatus for Boiling Foods.

A. Piece of Wood. *B.* Wire gauze Platform. *C.* Fish or Vegetable.
D. Boiling Water. *E.* Large Tin.

tin (15 ins. high \times 6 ins. wide), and leave for 15 mins., *i.e.*, until cooked (see Fig. 24). Lift out the gauze, drain the fish thoroughly, and weigh the whole.

Example :—

			ozs.
Weight of cod taken	...	=	$5\frac{1}{2}$
" " gauze platform	...	=	$1\frac{1}{2}$
\therefore the total weight	...	=	7
Weight of the whole after cooking, draining, and cooling	...	=	$6\frac{1}{3}$
\therefore the loss in weight	...	=	$\frac{2}{3}$
And percentage loss	...	=	12.1
			F 2

Another experiment gave a loss of 13·7%. The water used had a distinct smell of fish, so that some substance must have passed through into it. The percentage of solids in raw fish was found to be 16 (*vide* Chap. II.), so that the loss of about 13% on boiling must of necessity be largely water, driven out by the boiling. It seems strange, perhaps, that this water is lost from the fish while it is surrounded with water, but such is the case. If the fish-water is evaporated to dryness and weighed, the exact amount of solid washed out may be found. This percentage, subtracted from the total loss, will give the actual loss of water, and so the amount of the two may be apportioned accurately.

It might be interesting at this point to make a slight digression respecting the value of fish as food. Fish in moderation is excellent, provided it suits the individual palate, but there is no connection between the amount of fish consumed and brain capacity. Although the element phosphorus is an invariable constituent of brain matter, and fish is phosphorescent, *i.e.*, slightly luminous in the dark, it is entirely fallacious to believe that fish-eating develops brain energy, or that fish contains large quantities of phosphorus.

Boiling of Potatoes.—It is usually stated in cookery books that new potatoes should be placed in boiling water and old ones in cold, the explanation given for the difference of procedure being, that new potatoes are smaller, and a quick heat penetrates and cooks through, whereas old potatoes are large, and boiling water at first would tend to cook the outside thoroughly, leaving the inner portion uncooked—a gradual elevation of temperature preventing this. From my experience, and that of others, there is nothing to warrant this difference of treatment. Many cooks use boiling water for all; others only cold. Some put the potatoes into boiling water and do not boil again. All agree that nobody could tell from the

appearance, how the potatoes had been boiled. Perhaps the belief in the necessity of different treatment for new and old potatoes is one of those traditional ideas handed down from cookery book to cookery book, and has never been thoroughly investigated.

Suppose we experiment with old potatoes. They have first to be peeled and rinsed, but in no case should they be left in water for any length of time. Occasionally, one comes across people who peel sufficient potatoes to last for two or three days and then leave them in water, to be taken out as required day by day. Why is this a mistake?

Expt. 55. Take some peeled potatoes, place in a clean iron spoon, and rest on top of a red-hot fire until nothing more will burn away. Take off the spoon by the help of a duster and allow to cool. Most of the water in the potato has been driven off. It will be seen that a small quantity of a substance is left, which is soapy to the touch, and which, on addition of water, easily dissolves, imparting an equally soapy feel to the water. This ash from potato, then, is easily soluble in water, and is, of course, disseminated throughout the potato. The result of letting potatoes stand in water is therefore obvious—some of the mineral ash will be lost. This mineral portion is almost pure potassium carbonate, and is very beneficial to the system. Still more loss is likely to result by continued soaking.

Expt. 56. Place some peeled potatoes in water, and leave for three days; much white substance is then noticed at the bottom of the vessel, and probably the next day the contents of the jar will have frothed over. Fermentation has taken place in this event; but a consideration of this may be deferred to Chap. VIII., where fermentation is discussed in bread-making. Peeled potatoes left exposed to the air rapidly turn brown. The explanation of this may also be deferred till Chap. VII., where the browning of raw fruits is explained.

The loss that peeled potatoes undergo on soaking for a few hours in cold water is of the potassium carbonate. Unless a milkiness is noticed, no starch (the white substance which may collect at the bottom) is being lost. *What is the ideal way to boil potatoes so as to avoid loss of food material?* Suppose we investigate by boiling potatoes (1) peeled in the usual manner, and (2) in their skins or jackets.

Expt. 57. (1) Weigh some peeled potatoes, place on the gauze platform, and suspend in cold water. Now heat up this latter to boiling point and continue until the potatoes are cooked. Lift out the platform, drain, cool, and weigh.

Example :—

	ozs.
Weight of potatoes taken ...	= 9
„ „ gauze platform ...	= $1\frac{3}{4}$
∴ the total weight ...	= $10\frac{3}{4}$
Total weight after boiling, drain- ing, and cooling... ..	= 10
∴ the loss	= $\frac{3}{4}$
And the percentage loss ...	= $\frac{\frac{3}{4}}{9} \times 100 = 8.4.$

Examine the water in which the potatoes have been boiled. It has a characteristic smell of potato, and, evaporated to small bulk and cooled, has a distinctly soapy feel. This is due to the presence of potassium carbonate washed out of the potatoes. The late Mattieu Williams for this reason recommended the addition of a little potassium carbonate or bicarbonate to the boiled potatoes, to make up for the deficiency.

Expt. 58. (2) Repeat Expt. 57 using a clean potato in its jacket.

Example :—

			ozs.
Weight of potato taken	...	...	= $5\frac{3}{4}$
„ „ „ after boiling and			
cooking	...	...	= $5\frac{3}{4}$
			No loss.

Being a rather large specimen, it was boiled for 35 mins. On breaking, it was found to be thoroughly well cooked. *Notice the striking difference between the two losses—8·4% in the first and no loss in the second experiment.* Whatever the former loss might be (and it is certainly not all water, as we have proved), the second method is theoretically much better than the first. The objections to this method are of course the difference in flavour and the inconvenience of removing the skins before eating. Let us now examine the boiled potato from the first experiment, instead of the water, to see whether it is as rich in solid food as a raw potato, equal weights being taken. The solid substance in raw potato we have found to be 28% (*vide* Chap. II.). The percentage of solids in the boiled potato was determined and found to be only 17. Eleven per cent. of the food washed out on cooking!

Boiling of Turnip.—

Expt. 59. Peel a turnip, and boil until cooked, weighing before and after.

Example :—

			lbs	ozs.
Weight of turnip taken	...	...	=	2 6
„ „ „ after boiling and				
cooling	...	...	=	2 2

This large turnip was boiled for $1\frac{1}{2}$ hours.

Loss on boiling = 4

And the percentage loss $\frac{4}{32} \times 100 = 10\cdot5$.

The turnip water smelled strongly of the vegetable, some substance had therefore been lost from it. The percentage of solids in raw turnip was found to be 14. What is the percentage in boiled turnip?

Expt. 60. Dry the weighed 'boiled turnip (over steam) until constant in weight.

Example:—

	ozs.
Weight of the tin used for drying	
the boiled turnip =	3
Weight of the tin used for drying	
the boiled turnip + boiled turnip =	$8\frac{1}{4}$
∴ the weight of the boiled turnip	
taken =	$5\frac{1}{4}$
Weight of the tin + dried turnip =	$3\frac{3}{8}$
∴ the weight of solids =	$\frac{3}{8}$
Percentage of solids =	$\frac{\frac{3}{8}}{5\frac{1}{4}} \times 100 = 7.1$

It will thus be seen that the solid is only about one-half what it is in the raw turnip. The turnip water was evaporated to small bulk, cooled, and tested. It was quite sweet owing to the presence of a sugar known as grape sugar. In the boiling of the turnip, much of this is dissolved out.

Boiling of Cabbage.—The most noticeable fact about the boiling of cabbage is the exceedingly unpleasant smell of the water which is obtained. If this is kept for a day or so, the odour becomes worse. It is not suggested that the water is kept for this length of time, but the fact is stated as the result of test. After a week it can be smelled yards away, when, of course, quite cold. What I think is something of importance in the cooking of cabbage was established by the experiments on steaming, given in the next chapter. Experiments with cabbage must of necessity be rather crude owing to the difficulty of thorough straining after boiling.

Expt. 61. Wash a cabbage, boil it in water, using the supporting gauze platform, cool, and re-weigh.

Example of experiment:—

Weight of the cabbage taken ... = 2 lbs.

This was boiled for 40 minutes until thoroughly cooked.

			lb. ozs.
Weight afterwards ...	...	=	1 10 $\frac{1}{2}$
Loss in weight ...	...	=	5 $\frac{1}{2}$
Percentage loss ...	...	=	$\frac{5\frac{1}{2}}{32} \times 100 = 17\cdot2$.

What is the percentage of solids in raw cabbage and what in the boiled?

Expt. 62. Determination of the percentage of solids in the raw cabbage. Cut up the cabbage into small pieces, weigh it, and dry in a tin, using the steam from a pan of boiling water.

Example:—

			ozs.
Weight of tin used for the drying...	=	3	
" " " + raw cabbage	=	7	
∴ the weight of raw cabbage ...	=	4	
Weight of tin + dried cabbage ...	=	3 $\frac{1}{2}$	
∴ the weight of solid ...	=	$\frac{1}{2}$	
Percentage of solid ...	...	...	$\frac{\frac{1}{2}}{4} \times 100 = 10\cdot4$.

Evidently *very little* substance derived from the cabbage on boiling is able to cause a superabundance of malodour in the water. After *steaming* experiments, one came to the conclusion that the boiling of vegetables is a mistake, tolerated only for the sake of occasional convenience. One cannot, perhaps, reasonably expect a busy housewife who, in many cases, has to perform all the duties herself, to *steam* when boiling is quicker, since her time is limited.

There is no necessity to have an expensive apparatus for steaming. We must not, however, anticipate the subject-matter of Chap. VI.

Frying.—In frying fish there is something to be learned from the fish and chip potato salespeople, who generally fry in hot fat, usually lard. This is undoubtedly the most economical method. Many are under the impression that the fat in a frying pan is merely to prevent the article from sticking, and that the direct heat

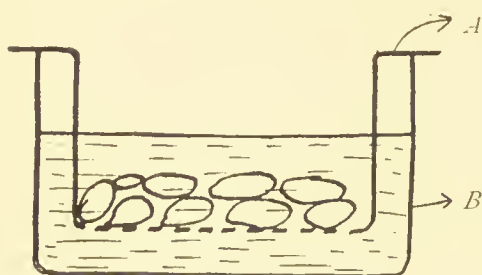


FIG. 25.—Apparatus for Frying immersed in hot Fat.

A. Perforated Platform holding the Food to be fried.

B. Large Tin containing hot Dripping or Lard.

from the fire does the frying. Frying implies cooking *with the fat*, and to do this properly the whole article should be covered. The use of a large tin is recommended; or a fish kettle almost filled with lard or beef dripping (see Fig. 25). This is heated up until the fat has melted, and continued until bluish

fumes are noticed coming from the fat. The article is then placed on the perforated platform, lowered into the hot fat, and left there until fried. The whole platform is then lifted out and excess of fat readily drained into the stock. It may seem rather extravagant to have, say, 3 or 4 lbs. of lard or dripping in use, but if a large quantity of fish or potatoes is to be cooked it is economy, as experience proves. Potatoes and fish may be fried in the same fat, but it is preferable to avoid having too many different articles cooked in the same fat. For small weights it is not necessary to have the fish kettle arrangement. I used a large circular tin about 15 ins. high by 7 ins. wide and

the wire gauze platform, similar to that used for the boilings. The disadvantage of this for household cookery would be, perhaps, that not much could be fried at one immersion. It served excellently for my experiments, however, as they were on a small scale. In order to investigate frying by immersion we must weigh not only the article before and afterwards, but also the tin containing the fat, and thus find out how much of the latter is lost from the tin by the operation. Use dripping or lard.

Expt. 63. Carry out an experiment on the lines indicated in the following example (cod used):—

	lbs.	ozs.
Weight of the tin and fat for frying ...	2	$8\frac{3}{4}$
Weight of the cod used		$4\frac{1}{2}$
Weight of the gauze platform...		$1\frac{3}{4}$

The fat was heated up to 392° F. before the fish was immersed. The introduction of the latter at once caused a fall in temperature to 340° F. After 5 minutes the fish was cooked.

	ozs.
Weight of cod after frying, draining, and cooling	$3\frac{1}{4}$
\therefore the loss in weight	$1\frac{1}{4}$
Percentage loss	$\frac{1\frac{1}{4}}{4\frac{1}{2}} \times 100 = 28.$

The tin and fat were then cooled and weighed, and found to be scarcely appreciably different from that at the commencement—about $\frac{1}{8}$ oz. as near as could be estimated. The saving in fat by this method is at once obvious, as one would be sure to use much more than $\frac{1}{8}$ oz. of fat for frying fish in a pan, and then what remained would not as a rule be used again.

Frying of Potatoes.—

Expt. 64. Perform the experiment as indicated in the following example :—

			ozs.
Weight of potato taken	...	...	= 4
„ platform	...	...	= $1\frac{1}{4}$
Initial temperature of the fat = 390° F.			
The potato was fried for 5 minutes.			
Weight of potato after frying,			ozs.
draining, and cooling	...	...	= $3\frac{1}{2}$
Loss in weight	...	...	= $\frac{1}{2}$
Percentage loss	...	...	= $\frac{\frac{1}{2}}{4} \times 100 = 12.5$.

Again there was no appreciable loss in weight of the lard. How much solid, if any, has passed from the fish and potato respectively? This can be ascertained by taking the cooked articles and finding the percentage of solids in them. In any case the losses will be certain to be largely water, but careful determination of the above will indicate exactly how much.

QUESTIONS.

1. Which method of cooking fish have you found to be less wasteful: (a) boiling; or (b) frying?
2. How would you prove experimentally that it is a bad practice to leave peeled potatoes soaking in water for hours or days?
3. Discuss in detail the advantages of boiling potatoes in their jackets over the ordinary method. What experiments have you performed to lead you to your conclusions?
4. What is the object of the fat in frying fish or potato? How would you find out whether it is more economical to (a) use a little fat, or (b) immerse in fat?
5. What are the main differences between the waters left from (a) boiling cabbage; (b) boiling turnip? Do these vegetables lose much in weight on boiling?
6. How would you find out whether the losses on boiling or frying potatoes are entirely due to water? Give exact experimental details.

CHAPTER VI

Steaming *v.* Boiling—The superior heat value of steam over boiling water—The advantages of steaming food—Latent heat of steam Steam-cookers—Vegetarianism.

THE steaming of food, in all cases except where dry heating is required, has been advocated for many years by certain small sections of the community. The strongest supporters of it, and to their credit, have been vegetarians, but owing to the comparative unpopularity of their ideas, and the difficulty of convincing the multitude, the steaming of food is even now rarely adopted in ordinary households. Ignorance of the capability of steam to adequately cook different articles is common among even educated people, and only a few years ago the statement that a cabbage could be cooked by steam was received with astonishment by a group of qualified cooks. Certainly quite a revolution has taken place since the day when a cabbage was boiled in half a dozen different waters for about the same number of hours. As an advocate of the steaming of food, I have encountered a surprising amount of prejudice, indifference, or apathy to learning anything about the method. Let us here consider without bias, both the advantages of and the objections to steaming.

Firstly, if water boils at 212° F. (or, what is the same, 100° C.), and the steam which comes from it is also at the same temperature, *how can steam be a superior cooking agent to boiling water?* And, secondly, *how can one account for the fact that cooking with steam invariably takes longer than with boiling water?*

Suppose we experiment to answer the first query. If it

can be shown that equal weights of steam and boiling water separately added to equal weights of cold water, at the same temperature, cause different elevations of temperature, it will prove that the two have imparted to the cold water, different amounts of heat. And if the rise in temperature in the first case is greater than that in the second, it will demonstrate the superior heat value of steam, and that equal weights of different substances may be at the same temperature and yet be able to give out very different amounts of heat on cooling through equal ranges of temperature.

Expt. 65. The tin can, which was used for the boiling milk and baking meat experiments, is fitted with a cork, or, better, a rubber stopper having a hole through it, and a piece of glass tubing is passed through this and bent twice at right angles (see Fig. 26). The other portion of the bent tube passes through a small hole in a cork fitted to a cylindrical lamp chimney and reaches half-way down. Another glass tube passes through another hole in a cork at the lower end of the chimney, at the side furthest from the top hole. Thus, instead of having one tube passing right through the glass, there are two. The reason for this will be seen later. A little water is placed in the tin α , the lid fitted on securely, and the tubes joined up in the proper manner. A small bright tin can, b , is then weighed, cold water poured in, the tin weighed again, and then placed so that the bottom tube from the cylinder passes into the water. Arrange the whole apparatus so that the tin b is supported on a block of wood of such a height that its removal will enable the tin to be slid away from the glass tube. Place a thermometer in tin b , and read the temperature. Everything is now in readiness. Heat up the water in the large tin α by means of a ring burner until it boils. Steam issues and soon fills the lamp chimney, but none

passes out until the latter is made hot. The reason for the interrupted tubing is so that any water produced by the condensation of steam will not run down into the tin *b* below, but stay in the chimney. One thus guarantees that nothing but steam issues from the bottom piece of tubing

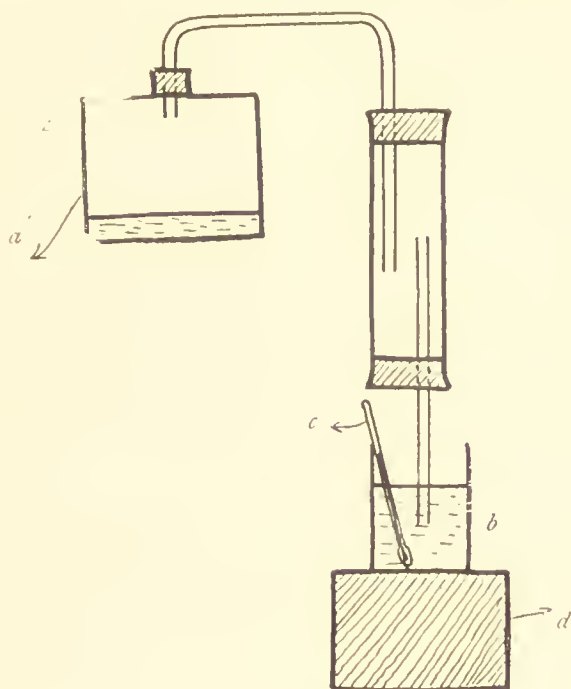


FIG. 26.—Apparatus for demonstrating the superior heat value of Steam.

- a.* Tin heated by Ring Burner or Stove. *b.* Tin.
c. Thermometer. *d.* Block of Wood.

and passes into tin *b*. Allow the steam to bubble into the cold water until the latter becomes quite hot. Stir gently all the time with the thermometer, and note when the temperature becomes, say, 180° F. When this temperature has been attained, remove the block of wood from under tin *b*, slide away the tin, and the next moment put out the light under the steam generator. Allow the

tin *b* to cool, take out the thermometer, and weigh again. The increase in weight will be that of the steam which has passed in. Make a note of this weight.

Expt. 66. Now take the same weight of water as before, at the same temperature, in the tin *b*, and, instead of passing steam in, quickly add to it a weight of boiling water equal to that of steam used in the previous experiment. Stir, and read the temperature. What is it? Is it higher or lower than it was in the first case? If lower, since equal weights of steam and boiling water were added to equal weights of cold water at the same temperature, it will follow that the steam has a superior heat value. If higher, the converse holds.

Example of experiments:—Eight ounces of water at 59° F. were placed in tin *b*. Steam was now passed in until the temperature was uniformly 180° F. (stirring continued all the time). On weighing after cooling and removing the thermometer, it was found that there were 9 ozs. of water in the tin, *i.e.*, 1 oz. of steam had passed in and raised the temperature of 8 ozs. of water from 59° to 180° F.

Eight ounces of water at 59° F. were again taken in *b*, and one-and-half ounces of water, heated to boiling point, quickly added to it. The temperature rose to 78° F. The $1\frac{1}{2}$ ozs. of water were taken to be quite sure that at least 1 oz. of boiling water was added, as a little would be certain to be lost in the process of heating up to the boiling point. Note the great difference! One ounce of steam raised the water to a temperature of 180° F, whereas 1 oz. or a little more, say $1\frac{1}{4}$ ozs., of boiling water only raised it to 78° F. Steam, then, has a heat value far superior to that of boiling water.

How can this big difference be accounted for? The answer will also explain the waste of heat by vigorous boiling when gentle simmering will suffice.

Expt. 67. A saucepan containing water is put on a gas ring and the light turned on full. When the water starts boiling, put in a thermometer and notice the temperature. Leave the light on full, and let the water boil vigorously. Does the thermometer indicate a higher temperature? No. Now turn the light low so that the water is just kept boiling. Is the temperature of the water any lower? No. Is as much gas being used, *i.e.*, is as much heat being imparted to the water as before? No. The extra heat must have gone to make *extra* steam, *i.e.*, to merely change the boiling water at a certain temperature into steam at the same temperature. Can this extra heat be recovered again? It can, as experiment proves. When the steam becomes condensed to water at the boiling point, all the heat which was required to change the physical condition from water to steam is given out again. **Such heat which is not observable by a thermometer is called Latent.** The latent heat of steam is the amount of heat required to change unit mass of water at the boiling point into unit mass of steam at the same temperature, or *vice versa*, it is the amount of heat given out when unit mass of steam at the boiling point becomes condensed to water, also at the boiling point.

What is the actual magnitude of the latent heat of steam? If we call the amount of heat which must be imparted to some ice-cold water to raise it to the boiling point 1, then it is found by experiment that the additional heat required to change it into the same mass of steam at the same temperature would be represented by about $5\frac{1}{3}$. Or, if the heat given out by the 1 lb. of boiling water on cooling to the freezing point be denoted by 1, the amount of heat given out by 1 lb. of steam on cooling in the same manner would be about $6\frac{1}{3}$, *i.e.*, $5\frac{1}{3}$ in addition to the 1. It is therefore apparent that vigorous boiling means constant absorption of a great amount of heat.

In the last chapter we spoke about applying the methods of the manufacturing chemist to domestic science, and

utilising something which is often wasted. What happens to the steam which comes from boiling saucepans? In most cases it is wasted. But steam is too valuable to be thrown away. Of course, some articles have to be cooked with the pan lid off. But where the lid has to be kept on, why not utilise the heat from the steam? How? The lids could be made concave instead of convex upwards so that a dish could be cooked or heated up in the pan lid by means of the steam generated in boiling the water for the other article. You will not find a manufacturing chemist wasting steam. A revolution in the salt industry has resulted owing to the working of patent processes, whereby heat is utilised from one crystallising pan to another. The best method of using steam in the kitchen, however, is to have it passing into a steam cooker. This will be discussed later on.

With regard to the usual objection, that cooking with steam is slower than with boiling water, we must again consider the amounts of heat contained in the two. By collecting and condensing all the steam used for cooking some meat, this was found to be not more than 3 to 4 ozs. Suppose we say 4 ozs. as a maximum. Would 4 ozs. of boiling water cook a joint of meat? It would not nearly cover it. The amount of water to cover the articles cooked would be at least 20 to 30 ozs. What is the relative amounts of heat contained in 3 ozs. of steam, and 30 ozs. of boiling water? If the steam condenses when it cooks (and of course it does) and then cools, the amount of heat given out may be represented by about 18 units, but the amount of heat which would be given out by the 30 ozs. of boiling water would be 30 units. Moreover, if it takes 40 minutes to steam an article of food, and the total mass of steam coming into contact with it is only 3 ozs., it means that for any one minute $\frac{3}{40}$ oz. of steam comes into contact with the food, whereas when boiling it, all the boiling water, say, 30 ozs., is in contact

the whole time. The amount of heat contained by $\frac{3}{40}$ oz. of steam is very much less than that contained by 30 ozs. of boiling water—the ratio is about 1 to 60. But if $\frac{3}{40}$ oz. of boiling water, were used, the ratio of the amount of heat contained by the steam and the boiling water would be about $6\frac{1}{3}$ to 1, or 19 to 3.

Steam Cookers.—There is nowadays no necessity to spend much money on a steam cooker. One could very easily utilise the steam from a pan of boiling water containing a cooking article, by having a perforated platform fitted to the top of the pan. The article to be steamed could then be placed in this, and the whole covered with a pudding bowl. Or, better, have a tin vessel made to fit the pan, and provided with a lid. The steam from the pan passes into a steam flue at one side, and cooks the food in the compartment. These methods of using what would otherwise be waste steam are only briefly mentioned to indicate what can be done. Many firms (such as Messrs. Gamage and Hutchings) now supply well-made steam cookers for a few shillings, and it is unnecessary to incur much expense or trouble in order to possess well-appointed apparatus. The one I use and can recommend (Messrs. Hutchings') has four compartments all heated from one boiler by means of a ring burner or jet. Perforated false bottoms are provided which curve upwards so that the condensed steam from the food runs away and does not make the latter sodden. *The most satisfactory feature of steaming is that it is practically impossible by this method to over-cook food*, which is not so in boiling, baking, or frying (see Figs. 27 and 28).

Each compartment of Hutchings' patent is provided with a valve, so that any one compartment may be shut off from the action of the steam without having to bodily remove that compartment. The card of instruction supplied says in effect : "Three-quarters fill the boiler with water. Pull

out the valves to allow the steam to enter the cookers. Keep the water in the boiler constantly boiling; the steam will pass up the steam-pipe to each compartment. The lid will only fit in its proper place; this places the cap on the steam-pipe. No added water is needed to cook

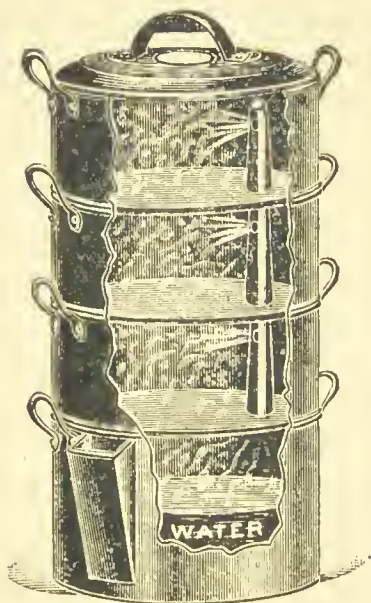


FIG. 27.—Steam Cooker.



FIG. 28.—Hutchings' Steam Cooker.

potatoes, turnips, carrots, onions, fruits, meats, eggs, fish, or puddings. Hominy, haricot beans, oatmeal, rice and macaroni require some added water. Keep plenty of water in the boiler. Do not often raise the compartments to see how the cooking is going on, as this wastes steam, and it is almost impossible to over-cook. When an article is finished cooking, shut the valve so that steam does not

enter that compartment, but the food is kept hot by the steam surrounding the tin."

As a rule, about $\frac{1}{3}$ extra time must be given for steaming, over that required for boiling; *e.g.*, suppose potatoes are boiled in 28 minutes, the time required for steaming would be about 37 to 38 minutes, and so on. The different flavours from foods are not mixed in this cooker.

Example of Quantitative Experiments on Steaming.

Expt. 68. An ordinary small dinner consisting of fish, beef, potatoes, cabbage and turnips was cooked. The times required were calculated according to the weights taken, and fixed at $1\frac{1}{2}$ hours for the turnip, 50 minutes for the beef, $\frac{3}{4}$ hour each for the potatoes and cabbage, and 16 minutes for the fish. The lid was fixed in position when all was in readiness. The weights of the different articles are not given, as it would be better exercise for the pupil to choose her own. As the respective times required passed, the valves of the particular compartments were closed so as to stop the further entrance of the steam. After the full time the light under the boiler was turned out (no more water has to be added as a rule), the compartments separated, cooled, and then the foods weighed. Scarcely any appreciable loss in weight was noticed in the potatoes, cabbage and turnip; about 10% in the fish; and 18% in the beef.

The figures for the losses sustained on boiling and steaming are as follows:

Boiling :—			Steaming :—		
		%			%
Beef ...	...	27.1	Beef ...	...	18
		20.5			
Potatoes	...	8.4	Potatoes about		2
Cabbage	...	17.2	Cabbage „		2
Turnip	...	10.5	Turnip	...	4.4
Fish ...	...	12.1	Fish ...	...	10
		17.3			

Example of experiments:—

The water left in the compartments by the condensation of the steam averaged about 4ozs. in each, and, although it did contain some solid material steamed out of the food, it held very little compared to that dissolved out on boiling. *The flavour of the steamed article is far superior to that of the boiled.* In fact, I feel sure that nobody knows what the flavours of potatoes and cabbage really are until they have tasted the steamed varieties. The water obtained from the cabbage was quite pleasant in odour, a great difference from that obtained from the boiled. Evidently, then, the disagreeable odour of the cabbage water is entirely due to boiling in much water, and must be some decomposition product induced by the bulk of the latter. Moreover, on being kept for a week, the strained cabbage water was almost as sweet as when fresh—a very remarkable example of the difference between boiling and steaming.

One must, however, avoid exaggerating the virtues of steaming, and making statements difficult to understand or justify. For example, the following is taken from a cookery book:—"Steaming. This conserves all their own juices which contain the various valuable natural salts, alkalies, etc., so necessary to health, and which we so vainly try to make up by the addition of crude minerals." The criticism of this is threefold, *viz.*, (1) It is impossible to conserve *all* the juices; (2) there are *no* alkalies in food; potassium carbonate is present in potatoes and is sometimes wrongly called an alkali. The most important real alkalies are caustic soda, caustic potash, ammonia, and lime, and these, as such, are absent from foods. (3) Potassium carbonate added in very small quantity to boiled potatoes, or mixed with common salt, would make up for the loss of this salt washed out on boiling. The word "crude" is one which the chemist would reasonably object to when applied to pure salts made in the laboratory.

To examine the statement that the boiling of vegetables dissolves out the mineral salts, the percentage of ash in raw and boiled turnip was determined and found to be .49 and .44 respectively, so that in this particular case there is very little mineral salt washed out.

I am convinced that the era of steaming food is at hand, owing to the superiority of this method and the ingenuity and enterprise of the different makers of steam cookers.

Vegetarianism.—A brief discussion of this important movement is introduced here, because the best results on vegetarian lines are only obtained, when steam is used as the cooking agent, instead of boiling water. Let us treat the matter by first giving the main considerations of the non-meat diet.

Arguments for Vegetarianism.—(1) Vegetarianism is not a diet of vegetables. One of its chief supporters has said: "The name 'vegetarian' will probably stick to us. Men do indeed laugh at it because they understand by it only a plant eater. But it has a very different meaning, for we derive the name from the Latin *vegetus*, which signifies vigorous, active, lively, animated. Logically then, a vegetarian is somebody sound in body and intellect." Vegetarianism is not necessarily asceticism or low diet.

(2) Many grades of vegetarianism are recognised, some people abstaining from *all* flesh products, including milk, butter and eggs, and consuming vegetable substitutes only.

(3) There is gross ignorance of food values amongst the masses, and much of the opposition to the vegetarian movement is pure prejudice.

(4) In answer to the question as to whether the protein part of food be obtained from meat, fish, and fowl, or from cheese, nuts, peas, beans, lentils, oats, wheat, etc., vegetarians maintain that the vegetable sources of protein are purer than the animal. There is also a different opinion as to the meaning of the terms "mixed diet." According to

vegetarians, it is not a diet containing meat, but one consisting of all the different kinds of food-stuffs in correct proportions, meat being quite unnecessary as a source of supply of protein.

(5) Again, it does not follow that "flesh makes flesh;" many believe that a certain amount of meat eaten, is an equal amount added to the flesh of the system.

(6) Vegetarianism is a return to a more natural diet, *viz.*, nuts, fruits, and succulent vegetables, as advocated by Baron Cuvier, Professor William Lawrence, Sir Charles Bell, Sir Richard Owen, and Charles Darwin. The following illustrious names are associated with a non-meat diet :—Pythagoras, Plato, Seneca, Plutarch, Milton, Newton, Sir Thomas More, Pope, Lord Chesterfield, John Wesley, Howard the prison philanthropist, Swedenborg, Benjamin Franklin, Shelley, Cardinal Newman, Sir Isaac Pitman, Wagner, Tolstoi, Bernard Shaw, General Booth, Robert Blatchford, Professor Mayor, Lord Lytton, and Lord Charles Beresford. Vegetarianism then, is consistent with physical and mental vigour and alertness.

(7) In some diseases, *e.g.*, rheumatism and gout, it is practically impossible to effect a radical cure without a discontinuance of meat eating.

(8) Finally, there are the rights of animals to be considered, and many are vegetarians on sentimental grounds alone. John Ruskin, in speaking of the 19th century Englishman, said :—"We shall be remembered in history as the most cruel, and therefore the most unwise, generation of men that ever troubled the earth, the most unwise in proportion to their science. No people understanding pain ever inflicted so much ; no people understanding facts acted upon them so little."

Arguments against Vegetarianism.—(1) The hereditary influence on diet is very great, so that it is almost impossible for anyone with a long ancestry of average or big

meat-eating individuals, to become a vegetarian. Again, whilst a non-meat diet may suit some, and be advisable in many cases, the stomach is the best guide, and where vegetarianism is not liked or disagrees, the diet is not suitable.

(2) The climatic factor is important. It is quite easy and natural to eat no meat in a hot country, but one invariably finds the inhabitants of cold countries eating meat. In Great Britain it is a common procedure to eat no meat during hot weather, but a fair amount in cold.

(3) There is a slight tendency to monotony and insipidity in a non-meat diet, and this is all against effective nutrition.

(4) A very important point, and one which should be worked out, and not merely spoken about, is the comparative digestibility of proteins from different sources. One would not be surprised to learn that the proteins from meats are, weight for weight, more digestible than those from vegetables, and therefore of greater food value.

(5) Modern civilisation with its many seemingly necessary artificial conditions and excitements demands some stimulant. Meat is, perhaps, the least harmful of stimulants, as well as a food.

(6) It has recently been established that hæmoglobin, the red colouring matter of the blood, and chlorophyll, the green pigment of plants, are closely related chemically. This may be interpreted in many ways, but it certainly shows that vegetarianism is only a matter of degree, *i.e.*, it is only comparatively dissociated from the taking of life; perhaps its advocates admit that.

QUESTIONS.

1. Describe how you would experimentally convince anybody that steam has, weight for weight, a greater heat value than boiling water.

2. What simple experiment would prove that pure boiling water and the steam from it are at the same temperature?

3. Cooking with steam takes longer than with boiling water. How can this be reconciled with the seemingly contradictory fact that steam has a superior heat value to boiling water?

4. Explain clearly what is meant by the latent heat of steam.

5. Two lbs. of steam at 212° F. are condensed and the resulting water cooled to 32° F. ; 3 lbs. of boiling water at 212° F. are cooled to 52° F. ; what are the relative amounts of heat given out in the two cases?

6. Sketch and describe a good form of apparatus suitable for steaming an ordinary dinner, so that all the articles can be cooked at the same time.

7. What have you found to be the principal advantages of steaming an article of food?

8. Criticise the following statement : "Steaming conserves *all* the juices of food." Do the figures obtained in your experiments support this view?

9. Describe the differences between boiled and steamed cabbage as regards (*a*) loss in weight experienced ; (*b*) taste ; (*c*) nature of the water left.

10. What erroneous impression prevails as to the meaning of the word "vegetarian"? What vegetarian foods are rich in protein, and how would you demonstrate the truth of your statements?

11. What are the main arguments for and against a non-meat diet?

CHAPTER VII

Dried fruits and vegetables—The changes which take place when these products are soaked in water—The nature of fruits and their value—Nuts as food.

MANY fruits when peeled and exposed to the air turn brown on the surface. Potatoes change in a similar manner. Evidently this acquirement of colour is dependent upon the air, as no browning takes place before peeling. Careful research has shown that these changes have been brought about by the presence of very small quantities of substances called **enzymes**. The name of each different enzyme ends in **ase**, and since these particular ones act only in the presence of air (which contains oxygen) they are called *oxidases*. The peeled apples, bananas, and potatoes kept away from the air entirely, do not discolour. Apart from this enzyme action, cut fruits exposed to the air shrivel up somewhat. Dried quickly in this way they will keep for a great length of time and may be bought at the grocer's shop.

Expt. 69. Expose about 6 ozs. each of peeled and cut apples, oranges (merely separated into their sections), and bananas to the air in shallow saucers, and weigh every day for a week. A gradual loss in weight will be noticed in the case of the apples and bananas, but very little in the oranges, the skin acting as a protection to the orange juice. After the week has passed, the apples will have lost about 40%, the oranges 10%, and the bananas 35% of their weight. Determine these losses. The substances are, however, obviously not dry (absolutely), so determine the total amount of solid material in each as follows.

Expt. 70. Dry weighed quantities (peeled and cut) in saucers by placing on pans containing boiling water. Continue until the weights are constant.

Percentage of Solids in Apples:—

Examples of Experiments :	ozs.
Weight of the saucer =	$7\frac{3}{4}$
" " + peeled and cut apples ... =	14
∴ the weight of apples taken =	$6\frac{1}{4}$
Weight of the saucer and dried apples ... =	$8\frac{3}{4}$
∴ the weight of dried solids =	1
And percentage of solids =	$\frac{1}{6\frac{1}{4}} \times 100 = 16$

Percentage of Solids in Peeled and Seeded Oranges.—The sections were broken to allow the juice to be exposed to the heating action of the steam from the saucepan of boiling water.

	ozs.
Weight of the saucer =	$7\frac{1}{4}$
" " + peeled oranges =	$14\frac{1}{4}$
∴ the weight of oranges taken =	7
Weight of the saucer + dried residue ... =	8
∴ the weight of dried solids =	$\frac{3}{4}$
And percentage of solids =	$\frac{\frac{3}{4}}{7} \times 100 = 10\cdot7$

Percentage of Solids in Bananas (peeled and cut up):—

	ozs.
Weight of the saucer =	$7\frac{1}{4}$
" " + peeled and cut bananas ... =	$12\frac{1}{4}$
∴ the weight of peeled bananas taken ... =	5
Weight of the saucer + dried residue ... =	$8\frac{1}{2}$
∴ the weight of dried residue =	$1\frac{1}{4}$
And percentage of solid residue =	$\frac{1\frac{1}{4}}{5} \times 100 = 25$

PERCENTAGE OF SOLIDS IN BANANAS 93

*It will thus be seen that bananas contain the most, and oranges the least, solid material available as food. Most ripe fruits contain a fair amount of sugar, and, at the same time, something which renders them "tart." This latter is called acid. It is a well-known fact that unripe fruits are more sour than ripe. The most valuable of these fruit acids are called **Malic** and **Citric**. How may one determine the relative acidity of different fruits?*

Expt. 71. Take a certain weight of the fruit, reduce it to pulp, and then macerate with water thoroughly. The acid will be dissolved out by the water. If a few drops of a solution of a colouring matter known as methyl orange are now added a pink colour is imparted. The methyl orange is said to be an indicator, and shows that an acid is present, because of the pink colour. Now prepare a solution of sodium carbonate or carbonate of soda, taking about 1 part by weight of it to 10 of water. Stir until dissolved and the solution is quite uniform in strength. Now add it, a drop at a time, from a glass tube by gently releasing the pressure of the index finger on the upper end (the tube being about 8 ins. long and almost filled with solution) until, on stirring, one drop of the sodium carbonate

	Water.	Free Acid.	Sugar.	Fibre.	Ash.
Apple ...	83.58	.84	7.73	1.98	.31
Pear ...	83.03	.20	8.26	4.30	.31
Apricot ...	81.22	1.16	4.69	5.27	.82
Bilberry ...	78.36	1.66	5.02	12.29	1.02
Blackberry...	86.41	1.19	4.44	5.21	.48
Gooseberry...	85.74	1.42	7.03	3.52	.42
Currant ...	84.77	2.15	6.38	4.59	.72
Grape ...	78.17	.79	24.36	3.60	.53
Raspberry ...	86.21	1.38	3.95	5.90	.49
Strawberry...	87.66	.93	6.38	2.32	.81

solution changes the pink colour to yellow. The solution of sodium carbonate slowly destroys the acid, as such, or neutralises it, and when this is completed, the pink colour gives place to a very pale yellow. Suppose 20 drops are added, and 40 drops for the same weight of another fruit. Obviously the amount of acid in the second fruit is twice that in the first. In a similar manner the relative acidities of a great many fruits may be determined.

The percentage amounts of the main constituents of some important fruits are tabulated on page 93.

Alteration of Dried Fruits on Soaking in Water:—

Expt. 72. As a typical case, take a weighed quantity of dried apricots, and soak in a jar or cylinder. A very marked increase in volume and weight takes place.

Example of experiment:—The operation was carried out in a cylindrical glass jar, so that the augmentation in volume could be obtained by noticing the rise of level of the fruit.

	lb.	ozs.
Weight of cylinder used =	9	$\frac{3}{4}$
" " + dried apricots =	13	$\frac{3}{4}$
∴ the weight of dried apricots taken =	4	
Total weight with added water ... =	1	10
∴ the weight of water used for		
the soaking =	12	$\frac{1}{4}$

The volume of the soaked fruit was found to be approximately *double* that of the dry. The weight of the soaked and drained fruit was found to be $7\frac{1}{4}$ ozs., *i.e.*, 4 ozs. gave $7\frac{1}{4}$ ozs., an increase of $\frac{3\frac{1}{4}}{4} \times 100 = 81\%$, or $7\frac{1}{4}$ ozs., of the

soaked apricots contained $\frac{3\frac{1}{4}}{7\frac{1}{4}} \times 100 = 44.8\%$ of added water. All fruits behave somewhat similarly to the apricots. The taste of the re-formed ordinary fruit, so to speak, is not quite the same as the natural, the enzyme action on drying altering the fruit slightly.

The Value of Fruits.—As will have been found by experiment, experience, or from the table given, fruits contain as a rule at least 80% of water, and this in a pure condition. There is also a fair amount of sugar, greater if the fruit is ripe; vegetable acids, such as malic and citric, which are very refreshing and have anti-scorbutic or cleansing properties, and also mineral salts, as indicated in the ash column of the table. An examination of these figures will show that strawberry contains the greatest percentage of water and grape the least; currant the greatest amount of free acid and pear the least; grape the most sugar and raspberry the least; bilberry the greatest amount of indigestible woody fibre and apple the least; bilberry the most mineral ash and apple and pear the least.

Dried Vegetables.—Dried peas, beans, and lentils were experimented with, and gave some interesting results. The loss in weight on drying the natural products is water, as would be gathered from previous work.

Expt. 73. Determine the alteration in (a) volume, (b) weight, and (c) nature, on soaking dried vegetables in water.

Example of experiments with peas:—

(1)

Weight of the glass cylinder graduated				
to 100 measures	...	...	...	= 5 $\frac{1}{3}$ ozs.
Weight of the glass cylinder graduated				
to 100 measures + dried peas	...			= 6 $\frac{1}{2}$ "
∴ the weight of dried peas taken	...			= 1 $\frac{1}{6}$ "
Volume of dried peas	...	...	...	= 50 measures.

After soaking for three days the volume of peas had increased to 100 measures, *i.e.*, 100% increase.

(2)

ozs.

Weight of the glass vessel	...	...	...	= 3 $\frac{1}{2}$
" " " " + dried peas	...			= 10
∴ the weight of dried peas	...			= 6 $\frac{1}{2}$

Water was poured in, and the soaking allowed to proceed for three days. On pouring off the excess of water, the peas were found to weigh 13 ozs., *i.e.*, $6\frac{1}{2}$ ozs. of dried peas gave 13 ozs. of soaked peas, or 13 ozs. of the soaked peas contained 50% of added water. What does this show? Are the soaked peas similar to those coming from the pod? Determination of the amount of water in peas from the pod gave figures varying from 11% to 22%. The soaked peas, however, contained 50% of water, so that, weight for weight, or bulk for bulk, the latter do not contain so much solid matter as the former. How is the large increase in weight and size on soaking dried peas in water to be accounted for? Also the fact that the residual water poured off after soaking contains some substance, as evidenced by the smell and colour? By **Osmosis**, *i.e.*, passage of water into the pea, in the first case, and by **diffusion** of substances from the pea, in the second. Equilibrium seems to be established when the peas have swollen to twice their size and have doubled in weight.

Expt. 74. With beans.—Proceed as with the peas.

Result of experiment:—Full details need not be given respecting the soaking of dried haricot beans; as peas, they almost exactly doubled in size and weight. The percentage of water in the ordinary beans varies from 13.6 to 14.3, so that, as with the peas, soaked beans are not so rich in solids as in the ordinary or uncooked state. A noteworthy fact regarding beans is the nature of the substance left after they have finished soaking. It has a very pronounced smell, resembling prussic acid, and very quickly causes a headache when breathed. It would most probably have a toxic action if drunk. Many members of the bean family contain small quantities of substances which, in presence of water, are decomposed, yielding a little prussic acid. The taste and smell of bitter almonds will convey a good idea of prussic acid. Prussic acid is poisonous in any but

very small doses, and several cases of poisoning have been met with, principally amongst children, through the eating of one or two dry haricot beans. In these cases the saliva brings about the decomposition of the cyanogenetic glucoside (the name of the substance present) with the production of a little of the poisonous acid.

Expt. 75. With lentils.—Proceed as with the peas and beans.

Result of experiment :—The dried lentils did not quite double in size and weight, but were not more than 5% less than these results. The percentage of water in ordinary lentils is 12.51. Peas, beans and lentils (leguminous products or pulses) are very rich in protein, carbohydrate and ash, and, as mentioned in the previous chapter, they constitute a great source of supply of protein to the vegetarian. All of them readily respond to the tests for these foodstuffs as given in Chap. II. Whole lentils are comparatively little used by the great majority of people, and it is sometimes a difficult matter to obtain them at a moment's notice from the grocer.

Nuts as Food.—The recognition of the value of nuts is very tardy. There is even now a deep-rooted prejudice against them. Most people look upon them as the unconsidered trifle to accompany wine after a big dinner, or something to occupy the time with between the meals of festivals such as Christmas Day. Nuts and meat are a bad combination, but nuts alone, replacing meat, are excellent if liked. Nuts are very rich in protein and fat, as a rule, and the number of nut foods on the market is now quite large, mainly due to the untiring efforts of manufacturers of vegetarian products. Meat and nuts together might easily result in a diet too rich in flesh-forming ingredients. When nuts are taken after a big dinner, the digestive juices have been operating for some time, with the result that the nuts may lie a hard undigested

mass on the stomach. Nuts, owing to their large fat content, require an alkaline medium for proper digestion or an anti-rheumatic condition of the blood. Much meat-eating develops acidity, the exact reverse of alkalinity, and this retards their digestion. Undoubtedly nuts are a purer source of protein than meats, and at many sanatoria for the treatment of rheumatic and gouty affections, a nut and fruit diet is the established regimen. Nuts are best eaten in their natural state, but are often made up into dishes resembling meat both in appearance and flavour.

QUESTIONS.

1. Describe carefully the different changes which occur when peeled and cut fruits are dried by exposure to the air.
2. How would you determine which of the following fruits contains the greatest and which the least solid material : (a) strawberry ; (b) orange ; (c) apple ; (d) banana ?
3. Sour apples and lemons are supplied. Determine their relative acidities.
4. What are the main points of value of fruits ?
5. Would it be possible to arrange a fruit diet sufficiently nourishing to support life, and without the necessity for including liquid ? If you think so, what fruits would be most suitable ?
6. What important changes in (a) weight ; (b) size, occur on soaking dried peas and lentils in water ?
7. Describe in detail how you would ascertain whether the increase in weight on soaking haricot beans is entirely due to inflow of water, and whether any loss of solid substance from the beans occurs.
8. How would you experimentally compare the food values of (a) lean beef ; (b) Barcelona nuts ?
9. What mistakes are frequently made which prejudice the use of nuts as food ?

CHAPTER VIII

Flours, their natures and strengths—The tenacity of flour—Qualities of flour for bread-making—Panification, fermentation, and the preparation of dough—Yeast, properties of good yeast, and its action in bread-making—Other methods of making dough—Soda bread—The other constituents of bread and the action of heat on them—Bread and bread-baking—Loss in weight on baking and the nature of the loss—Percentage of solid material in the crust and crumb, and also the amount of water-soluble material—Toast—Adulteration of flour and bread.

ALTHOUGH flour is perhaps the commonest and best known article of food, there is much lack of knowledge respecting it. The recently largely advertised agitation in favour of "standard" bread has, fortunately, drawn the attention of people to the subject of bread and bread-making, if it has done nothing else. It is surprising what faith the community in general has in its millers and bakers. The dairyman has to fulfil the letter of the law regarding his milk, and no doubt the millers of flour and bakers of bread will ere long have to meet similar obligations. Not only are most people unaware of the effects of climate, soils, manure, and moisture, on the growth and development of wheat, but they are also quite unable to test the quality of a specimen of flour. Very many housewives are excellent judges of the different joints of meat, so that it is not expecting too much that they should also be able to pass some judgment on flour. Flour is bought in many cases without being seen, and is ladled into a bag by the shopman and parcelled up without any questioning. Very few buyers would ask whether the flour were a "strong," a "medium," or a "weak" one, or employ any of the other

customary technical terms in estimating its quality. Flour to most, is simply flour. There are, however, a great many grades, high and low. It is certainly an extremely difficult matter for the miller to obtain absolute uniformity or guarantee a fixed standard of composition, flavour, and texture. Flour in this respect varies almost as much as milk, and there will be the same difficulty about fixing the legal limits for flour as there was with regard to milk. There is little doubt, however, that an equitable standard will be decided upon eventually which will ensure good quality to the general public, and, at the same time, keep millers and bakers always careful for the common weal, without any sense of persecution. Just as the farmer cannot be blamed, except in a small minority of cases, for the slight variations in the milk quality and production of his cows, so must the miller be absolved from all intent to avoid uniformity.

Circumstances Affecting the Growth and Quality of Wheat.—There are many factors governing and modifying the growth and development of wheat. Messrs. Lawes and Gilbert, in their long and famous series of experiments at Rothamsted, found that manures have very little influence. Mr. F. T. Shutt, of the Central Experimental Farm, Ottawa, Canada, has recently shown that the amount of moisture in the soil is a greater factor than the amount of soil constituent giving rise to protein substance in the grain. The protein, or flesh-forming portion of the wheat grain, is called **Gluten**; the constituent of the grain present in largest quantity is **Starch**. In the Ottawa experiments it was found that a moist soil produces grain with a low gluten but a high starch content, or, *vice versâ*, a dryer soil produces grain containing more gluten and less starch than the former. It thus follows that wheat of the same variety grown in the same locality but in different fields, may differ quite

considerably. The difficulties of the miller to obtain uniformity in quality of flour are at once obvious. The *first* important factor governing the growth of wheat and the development and composition of the grain, therefore appears to be the amount of moisture in the soil. The *second* is abundance of sunshine. In our tests for food-stuffs we relied upon the burning feather smell evolved on heating, as a method of recognising protein. In order that protein food may be built up it is necessary to have present a simple substance, or "element," as it is called, to which the name *nitrogen* has been assigned. This element is a gas, but it occurs in a disguised, unrecognisable, or combined form in the solid proteins. (Full details about elements and compounds are given in Chap. IX.) Proteins are said to be nitrogenous or rich in nitrogen. With regard to the second factor—sunshine, in the growth of wheat, chemical investigations have shown that the wheat plant takes up nearly all the nitrogen and mineral salts or ash constituents, *i.e.*, almost as much as the matured plant will contain, at the time of blossoming; but, on the other hand, it continues to store up starch (which contains no nitrogen) so long as the plant is green. Consequently, slowly matured grain will contain proportionately less protein and more starch than the quickly matured, a result which seems to show that excessive moisture in soil results in slow maturing, as these same facts were arrived at with a moist soil. Slowly matured grain will be plump, *i.e.*, give more bushels of flour per acre than the quickly ripened.

Varieties of Wheat.—The wheat cultivated is the *Triticum vulgare*, of which there are two varieties, *viz.*, the *Triticum aestivum*, or summer wheat, and the *T. hybernum*, or winter wheat. Examples of spring or summer wheat are those grown in Manitoba. These are sown in the spring and harvested in the autumn. Winter

wheats are those such as are cultivated in Ontario. They are sown in the autumn and harvested the next summer. Spring or summer wheats are *harder*, as a rule, than winter wheats, but unfortunately, owing to the fact that soft wheats produce more bushels per acre, a greater quantity of the softer, heavier yielding varieties is grown.

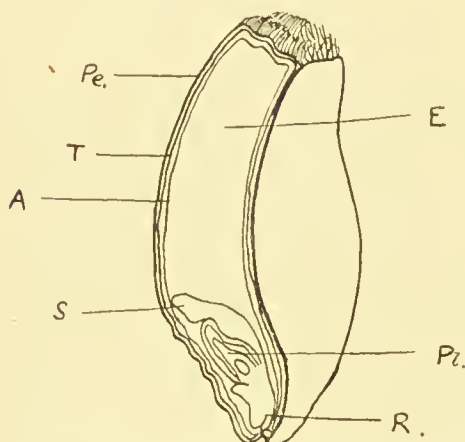


FIG. 29.—Section of Grain of Wheat.

- | | |
|---------------------------|--------------------------|
| <i>Pe.</i> Pericarp | } = Fruit Coat = Bran. |
| <i>T.</i> Testa | |
| <i>A.</i> Aleurone Layer. | Chiefly Protein. |
| <i>E.</i> Endosperm. | Chiefly Starch. |
| <i>S.</i> Scutellum | } = Embryo Plant or Germ |
| <i>Pl.</i> Plumule | |
| <i>R.</i> Radicle | |
- rich in Protein and Fat.

Milling of Flour.

—Before passing on to a brief consideration of this it will be desirable to examine what the wheat grain contains or how it is built up.

Expt. 76. If possible, examine a section of a grain of wheat through a microscope (see Fig. 29).

There are two layers of bran, the inner one rich in mineral matter; then the endosperm, the main constituent of which is starch; and the germ, rich in proteins and fat. In milling, the grain is first of all cleaned, and different kinds blended, if desired, to produce a requisite kind of flour.

Wheats are said to be "*strong*," "*medium*," or "*middle strength*," and "*weak*." The "*strong*" varieties are the Spring American or Canadian, Southern Russian, and Hungarian; "*middle*," those cultivated in Kansas, Argentina and India; and "*weak*," the English, Australian, Chilian, and Winter American and Canadian. The

strongest wheats are grown in countries with long, severe winters.

The steel roller mill process of making flour has been slowly evolved from the old stone method, owing to the increasing demand for a white flour. In the stone mills the whole of the flour was left in one "*grade*," as it is called, *i.e.*, the whole of the wheat was retained in the flour, and the germ and some of the bran layers were not removed in what is called the "*bolting*" or "*sieving*" process. The following are the recognised operations of steel roller milling:—(a) "*breaking*," *i.e.*, severing the wheat from the husk by placing between two rollers, one moving two and a half times as fast as the other; (b) *scalping*, *i.e.*, separating the kernel of the grain from the husk after each breaking; (c) *purifying*, *i.e.*, removing the light branny particles from the good *semolina* or *middlings*; (d) *rolling*, *i.e.*, grinding up the *semolina* or purified sections of the kernel of the grain. The siftings from each "*break*" are sorted by means of wire sieves and air currents into *flour*, *dunst*, *middlings*, and *semolina*, the *dunst* being the smallest granular stock, and the *semolina* the largest. In a few words, the milling operation is practically a gradual process of sifting, after the four above-mentioned operations have been performed. With each sifting some material fine enough for flour is obtained. The greater part of the **Endosperm**, or central portion of the wheat, is left in a coarse, granular condition known as the *semolina*. In the "*standard*" flour mentioned previously, this *semolina* is incorporated. It constitutes the whitest part of the grain and makes the strongest flour. The word "*grade*" is often used in connection with flour. *It signifies, as a rule, the flour obtained by one particular sifting.* A *straight grade*, however, is a flour obtained from the numerous sifting or dressing machines, blended. As many as six *grades* can be obtained from one variety, or *blend*, or "*stream*" of wheat. The *germ* is richest in protein and fat (as already mentioned), the inner bran

layers are next richest, and the *endosperm* is the poorest. It follows then that the whitest flour made from the endosperm is lower in protein, fat, and crude fibre, than if the whole of the grain were included, and somewhat poorer than the old stone ground flour, or the modern 80% "standard" flour.

Many fancy names are given to the different varieties of flour. Whatever meanings are attached to the expressions, "strong," "medium," and "weak," it is obvious that by mixing the wheats before milling, almost any desired strength may be obtained.

Characteristic Property of Flour.—It is well known that flour mixed with water becomes transformed into a tenacious or sticky dough. But few people are aware that this fact is almost alone characteristic of wheaten flour, and accounts for the much greater amount of wheaten bread made than of rye or any other cereal? Suppose we experiment.

Expt. 77. Take four lots of flour weighing about 4 ozs. each and place into four saucers. Also weigh out 4 ozs. of oatmeal and starch and put each into a similar saucer. Now add a little water to one lot of flour and continue stirring until the dough is obtained. Add methylated spirit to another lot of flour and stir. No amount of stirring or proportion of the spirit will cause the dough to be produced. Next add 4 ozs. of water to the third lot of flour and stir. The dough is not nearly so tenacious or sticky. We have "drowned the miller." To the last portion of flour add a little strong solution of salt (made by adding $\frac{1}{2}$ oz. of salt to about 5 ozs. of water) and stir. No dough is obtained. Add water to the oatmeal and stir up: no dough. Finally add water to the starch and stir: again no dough. What conclusions can be drawn from these tests? *The production of dough is dependent upon the use of wheaten flour and a certain amount of water (but not an*

excessive quantity of it). Alcohol, or very salty water is of no use, and neither is oatmeal. This characteristic *tenacity* of wheaten flour is of the greatest importance, as it enables the familiar spongy form of dough or bread to be obtained. To what is the tenacity due? Suppose we examine the average composition of white flour, with a view to finding the particular ingredient or ingredients.

							%
Ash (partly soluble) and principally potassium phosphate ... ..	...	...	...	...	...	...	7
Soluble constituents : A sugar called maltose ; gum ; dextrin ... ..	...	...	...	...	...	...	3.0
Insoluble constituents :	Protein ; gluten ...						12.0
	Starch ; woody fibre or cellulose						69.6
	Fat						1.2
Water... ..	...	...	...	...	...	...	13.5

Starch, the principal ingredient, is, as we have seen, unable to produce a tenacious dough, with water. The small quantity of sugar and fat cannot produce dough; nor can the very little gum. *The only remaining constituent able to confer tenacious properties is the gluten.*

In the analysis of the composition of white flour given above, the second and third divisions are labelled "Soluble Constituents" and "Insoluble Constituents." These are the substances soluble or insoluble in cold water. One may very easily determine the percentage of flour soluble in cold water.

Expt. 78. Determination of the Cold Water Soluble Proportion of Flour.—Take about 10 ozs. of white flour and slowly add to 1 pint or 20 ozs. of cold water, and thoroughly stir. After standing for three hours, and stirring for a few minutes at intervals of half an hour, leave the whole undisturbed for a day and then pass through fine muslin, resting on a gauze sieve funnel (see Fig. 30).

Then evaporate the clear aqueous extract to dryness in a weighed tin (a letter weigher is used for the weighings),

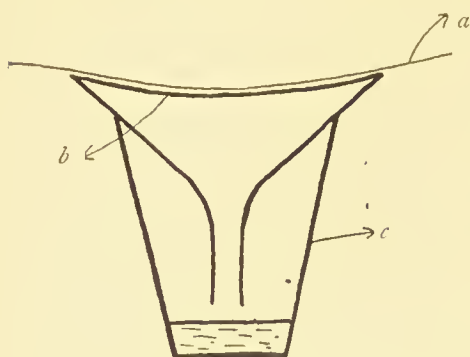


FIG. 30.—Determination of the Cold Water Extract of Flour.

a. Piece of fine Muslin. b. Wire Gauze.
c. Tumbler.

and thus obtain the weight of residue. In a sample experiment the weight of the clean dry tin was 3 ozs., and that of the tin and dry residue $3\frac{3}{8}$ ozs. Whence the weight of the water soluble part of flour = $\frac{3}{8}$ oz., i.e., $\frac{3}{8}$ oz. in 10 ozs. of flour, or $\frac{3}{8} \times \frac{100}{10} = 3.8\%$ approx-

ately, a figure which agrees very well with that given in the table.

Expt. 79. Separation of Gluten from Flour.—Take some flour and enclose it in a piece of fine muslin, so as to form a kind of bag. Place this in water holding with one hand and knead the flour thoroughly with the other under the water. A milky fluid is very soon obtained, instead of the clear water. Continue this kneading until almost all has passed out of the muslin, or until it ceases to make the water milky. Now open out the bag. A small quantity of a yellowish, sticky substance will be seen. This is the **gluten or flesh-forming ingredient**. Left for a few days it turns quite sour. In the form obtained by this kneading process it is called “wet gluten,” and the percentage of this might easily be obtained by weighing the flour started with, the resulting “wet gluten,” and then calculating.

Expt. 80. Determination of the Amount of Water in Flour.—This is of very great importance as it has a very significant bearing upon the strength of flour. Dry a

weighed quantity in a tin by means of steam. An experiment to determine this water is here recorded :—

Example of experiment :—

	ozs.
Weight of the tin used for drying the flour =	3
Weight of the tin used for drying the flour + flour used =	8
∴ the weight of flour used for the experiment =	5
Weight of the whole after drying over steam until constant in weight (about three days) =	7½
∴ the loss in weight ... =	½ oz. = water
And the percentage of water = $\frac{1}{2} \times 100 = 10$.	

Quality and "Strength" of Flour.—We have already indicated the varieties of wheat, generally known as *strong*, *medium*, and *weak*. Flours vary much in quality. It is impossible to tell the best flour by chemical analysis, but, within certain limits, it is easy to find out which flour will make the best bread. The flours from hard spring or summer wheats are usually granular or gritty, and do not easily "*pack*" when squeezed. *Soft* flours do. The *hard* flours are *strong* and make good bread; the *soft* are pastry flours and not good for bread. The baker likes a flour that will absorb water and yield a big weighty loaf of a desirable shape, of good colour and texture. Such a flour is called a "*strong*" one, but it is difficult to define strength in flour, and practically impossible in the present state of our knowledge to say exactly what it is in flour which makes one "*strong*" and another "*weak*." Jago, the English authority, defines **strength** as **the capacity of flour for absorbing water**, and treats the size, shape, colour, and texture produced from it, separately. The importance of an

experiment on the amount of water in flour is now evidenced. The less water there is already in the flour, the *greater* the amount it will take up on being made into dough, and the *heavier* the loaf; and, *vice versa*, the greater

quantity it *already* contains, the less will it require to produce the dough and the *lighter* the resulting loaf. Many experiments on strength may be performed: (a) by noting how much water has to be added to equal weights of different flours before doughs of equal consistency or tenacity are obtained, and (b) weighing the flour used, making up into bread, weighing this, and then calculating in each case the weight of bread which would be produced from 1 lb. of the different flours.

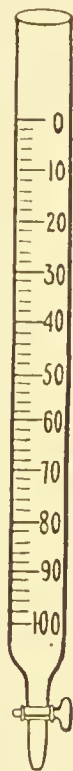


FIG. 31.—Burette able to deliver 100 Measures (Cubic Centimetres).

Expt. 81. Experiments on the Strength of Flour. (a).—Take equal weights of six different white flours and place in saucers. Run in water from an instrument called a burette (see Fig. 31) until the correct and equal consistency of dough is obtained. [A burette is a glass apparatus, graduated, and provided with a tap near the bottom. The numbers go

downwards as the burette delivers water downwards. The amount of water run out and, therefore, the quantity used for the experiment, is easily read off by observing the number opposite the level of water before and after running out, and subtracting the first from the second.]

Example of experiment :—

With six specimens of white flour examined, the amounts of water run in before the doughs of equal consistency were obtained, were 48, 50, 51, 52, and 56 measures (cubic centimetres) respectively. Consequently, although the strengths were almost the same, the strongest required 8 measures more water than the weakest, or was $\frac{8}{48} \times 100 =$ about 16% stronger in water absorption capacity.

The strength experiments depending on the bread productions are, perhaps, more reliable. Without saying here how the bread was made, identical recipes were used for all grades of flour, and, as far as possible, the baking was carried out under similar conditions, and the resulting loaves were evenly baked.

Expt. 82. **Experiments on Strength of Flour.**
(b).—

1 lb. of a white flour yielded 1 lb. $5\frac{1}{2}$ ozs. of soda bread, or
 " " " 1.344 lbs. of bread.

Expt. 83.

1 lb. of a white flour gave 1 lb. 6 ozs. of bread, or
 " " " 1.375 lbs. of bread.

Expt. 84.

1 lb. of "standard" flour gave 1 lb. $6\frac{1}{2}$ ozs. of bread, or
 " " " 1.4 lbs. of bread.

Expt. 85.

1 lb. of "Artox" whole-meal flour gave 1 lb. 7 ozs. of bread, or
 " " " 1.43 lbs. of bread.

From these results it will be seen that the flour *strongest* in water-absorptive power was the *whole-meal*, and the

first flour used for the preparation of soda bread, the *weakest*. As, however, the soda bread was made under different conditions, it is best to call the second flour tested, the *weakest*. The recognised figures for *strong*, *middle-strength*, and *weak* flours are as follows:—A sack of 280 lbs. of *strong* flour will give 440 lbs. of bread, *i.e.*, 1 lb. will yield 1 lb. 9 ozs., or 1.57 lbs. of bread. A sack of 280 lbs. of *medium* flour will give 384 lbs. of bread, or 1 lb. yields 1 lb. 6 ozs., or 1.37 lbs. of bread. A sack of 280 lbs. of *weak* flour will give 360 lbs. of bread, or 1 lb. yields 1 lb. $4\frac{1}{2}$ ozs., or 1.28 lbs. of bread. It will thus be noticed that the flours used for our experiments were about *medium strength*, the strongest being between the regulation medium and strong.

As a result of their investigations into what constitutes or causes strength in flour, Humphries and Biffen say it is the capacity for making well-piled loaves. This suggests that the primary factor is the size of the loaf. The different views which have been expressed regarding the possible factors governing the volume, shapeliness, and texture of the loaf, are many and diverse. The oldest idea was that the tenacity of the gluten enabled the dough to be "*blown up*" or "*raised*," and therefore the greater the quantity of gluten, the stronger the flour. This, however, is not reliable, because, in some cases, the flour with the greatest percentage of gluten does not give the biggest loaf. Others drew attention to the fact that the gluten in some flours is soft and flabby, whilst in others it is firm and tenacious. Attempts were made to ascertain the quality of the gluten by determining the ratio between the weights of wet and dry glutens, their expansive power under the action of heat, and also the proportions of two constituents of the gluten (for gluten is not a single substance), **gliadin** and **glutenin**. Again, the view was expressed that it is the *actual amount* of gliadin in the gluten which confers strength and nothing else. Finally

there is the theory propounded by Professor Wood, of Cambridge University, that the size of the loaf is dependent upon the amount of sugar present, together with that formed during what is called "*diastatic fermentation*" (for explanation of this see "Fermentation" further on in the chapter) and that the shape depends upon the physical properties of the gluten as modified by the presence of



FIG. 32.—Bread from straight grade Flour from : 1. Manitoba Wheat, and 2. Ontario Winter Wheat.

different proportions of salts. The flour trickery exposed by J. McPhail about a year ago, seems to support Wood's views. McPhail found that a little "phosphate powder" was being added to give a bigger and more weighty loaf. This will be considered when dealing with the adulteration of flour.

Many excellent and elaborate experiments have been carried out for the Ontario Department of Agriculture by two of the staff of the Agricultural College, Professor Harcourt and Miss Purdy, and the results of some of these are now given, with photographs of the actual loaves

made. Twelve ounces of flour were used for every loaf. Fig. 32 shows bread made from an average straight grade flour, the first being **Manitoba Spring** and the second **Ontario Winter** wheat. The former is a good bread flour; has more and better gluten; greater power of absorbing water;

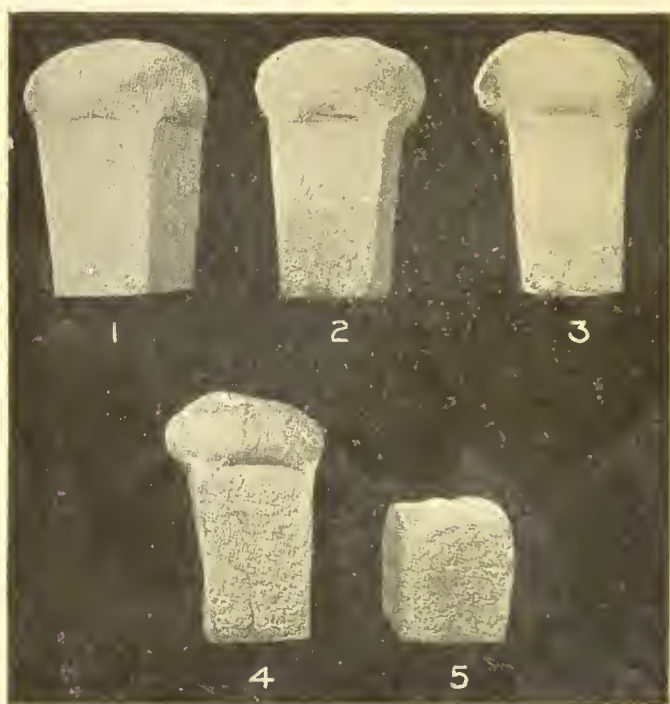


FIG. 33.—Bread from five grades of Flour made from one stream of Manitoba Wheat. No. 1, Patent; No. 2, Baker's Grade; No. 3, Straight Grade; No. 4, Low Grade; No. 5, Red Dog.

greater expansion; and is better in every way than the latter except in flavour. Fig. 33 shows loaves of bread made from several of the grades of flour from one *stream* of **Manitoba** wheat. The appended figures show the percentage of "wet gluten," water absorbed, weight of the loaf in ounces, and the size and quality of the loaf:—

Flour.	Per-centage of wet gluten.	Per-centage of water ab-sorbed.	Weight of loaf in ozs.	Size of loaf in pints.	Quality of loaf.		
					Colour.	Texture.	Appear-ance.
Patent ...	32.16	66.5	18.3	4.7	100.0	100.0	100.0
Bakers' ...	34.46	65.6	18.18	4.6	97.0	99.0	100.0
Straight grade	34.09	65.9	18.24	4.6	96.0	99.0	100.0
Low grade ...	41.13	72.4	18.7	4.18			
Red Dog ...	30.68	78.2	18.5	4.18			

The figures for quality were obtained by assigning 100 each to the **Patent** grade for colour, texture, and appearance and marking the others accordingly. The **Patent** flour made the *largest* loaf, and the **Red Dog** the *smallest*. The



FIG 34.—7 Loaves from 7 different varieties of Wheat.

Patent loaf was the best, although it contained almost the lowest amount of gluten in the wet condition. The first three are good flours, but the low grade is poor in quality, and the **Red Dog** suitable for dog biscuits only. Fig. 34 shows seven loaves from seven different varieties of wheat grown on the experimental plots of the Ontario Agricultural College. It illustrates the very wide variation in quality of bread which the different varieties are capable of producing.

Flour.	Per-centage of gluten.	Per-centage of water ab-sorbed.	Weight of loaf in czs.	Size of loaf in pints.	Quality.		
					Colour.	Texture	Appear-ance.
Bulgarian ...	26·87	47·4	16·16	3·7	97·0	97·0	100·0
Early Red Clawson ...	25·7	48·8	16·37	2·9	97·5	96·0	93·0
Kentucky Giant ...	27·10	48·8	16·23	3·4	99·0	102·0	95·0
Early Genesee Giant	26·87	48·8	16·23	3·8	100·0	100·0	100·0
Geneva ...	28·40	47·4	16·30	3·3	98·0	97·5	98·0
Dawson's Golden Chaff...	22·50	48·8	16·69	3·2	90·0	94·0	96·0
Egyptian Amber ...	27·50	48·8	16·77	3·6	99·0	7·90	100·0

Egyptian Amber gave the *best* yield of bread, the **Early Genesee Giant** the largest loaf and the best quality of bread, whilst **Dawson's Golden Chaff** and **Early Red Clawson** gave the smallest loaves and the poorest quality of bread. It has been already mentioned that different localities produce very different wheats from the same seed. Fig. 35 shows the difference in size of two loaves made from **Ontario Winter** flour grown in two different localities.

The larger loaf was also much superior in colour, texture, and general appearance.



FIG 35.—Bread from Ontario Winter Wheat grown in different localities.

Loaves from Blended Flours.—Fig. 36 is an illustration of the results of different blendings of flours, *i.e.*, mixtures of certain proportions of *strong* and *weak* varieties.

Flour.	Per-centage of gluten.	Per-centage of water ab-sorbed.	Weight of loaf in ozs.	Size of loaf in pints.	Quality of loaf.		
					Colour.	Texture.	Appear-ance.
No. 1...	34·09	68·8	18·4	4·8	100·0	100·0	100·0
„ 2...	32·31	66·2	17·9	4·7	99·0	99·0	98·5
„ 3...	31·86	64·6	17·4	4·2	98·0	98·5	96·0
„ 4...	31·41	62·5	17·5	4·2	95·0	98·0	95·0
„ 5...	28·97	61·4	17·2	3·6	96·0	96·0	92·0
„ 6...	30·52	60·9	17·2	3·3	95·0	95·0	90·0
„ 7...	29·63	52·2	16·8	3·2	94·0	94·0	87·0

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The table on p. 115 gives figures showing the change in yield of bread and the size and quality of the loaf in each case. Twelve ounces of flour were again used for each.

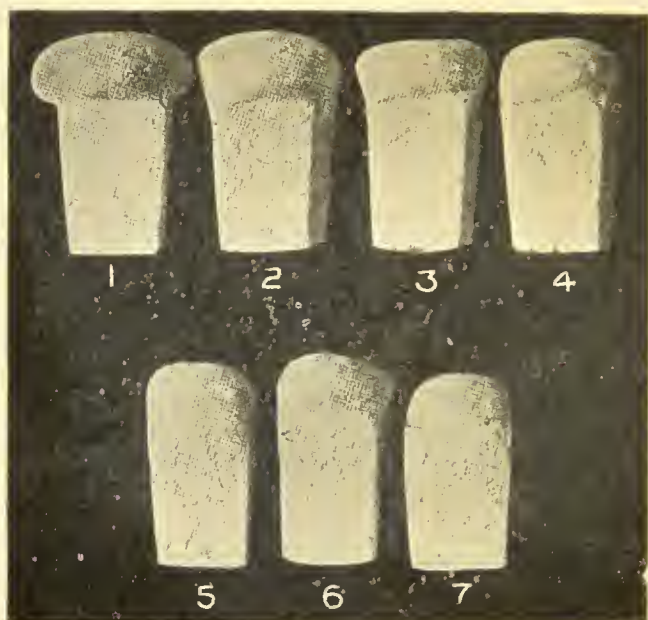


FIG. 36.—Loaves of Bread from Manitoba and Ontario Flours blended in the following proportions :—

No. 1.	100°/o	of Manitoba.				
No. 2.	60°/o	"	"	and 40°/o	Ontario Soft Flour.	
No. 3.	50°/o	"	"	" 50°/o	"	"
No. 4.	40°/o	"	"	" 60°/o	"	"
No. 5.	30°/o	"	"	" 70°/o	"	"
No. 6.	20°/o	"	"	" 80°/o	"	"
No. 7.	...	...	...	100°/o	"	"

The illustrations and figures are sufficiently explanatory without going into details. No. 4 is a useful blend and gives a good loaf. Let us now conclude our consideration of strength of flour by bringing the weights of the loaves, made in these Canadian experiments, into line with our experiments, *i.e.*, by calculating the weights of the

loaves which would have been produced from 1 lb. of flour in each case :—

Flour				lbs. of bread
Patent	...	...	1 lb. of flour would make	1·525
Bakers'	...	...	" "	1·53
Straight Grade	...	...	" "	1·52
Low Grade	...	...	" "	1·56
Red Dog	...	...	" "	1·54
Bulgarian	...	...	" "	1·35
Early Red Clawson			" "	1·364
Kentucky Giant	...	...	" "	1·36
Early Genesee Giant			" "	1·35
Geneva	...	...	" "	1·39
Dawson's Golden Chaff			" "	1·39
Egyptian Amber			" "	1·397
No. 1	...	...	" "	1·53
" 2	...	...	" "	1·5
" 3	...	...	" "	1·45
" 4	...	...	" "	1·46
" 5	...	...	" "	1·43
" 6	...	...	" "	1·43
" 7	...	...	" "	1·40

Bleaching of Flour.—Newly milled flour does not give such good results as a flour which has been kept for two or three months in a suitable place. Why this should be, is not exactly known. A certain amount of drying or loss of moisture occurs, of course, and this will consequently increase its water-absorbing power. Ageing also increases the expansive power and improves the colour. These remarks apply to the still largely used white flour. Bleaching the flour chemically seems to have a somewhat similar effect as ageing, but this artificially treated flour is never equal to the naturally aged. It is always whiter and lacking in the desirable creamy shade. The general public are undoubtedly largely to blame for this bleaching,

owing to its unreasonable demand for a white flour, under the mistaken impression that whiteness in everything which normally approximates to that colour signifies purity. A universal and constant demand for a naturally creamy coloured flour would have given millers no cause for the exercise of their inventive faculties on the question of bleaching. There is now, however, much more rational bread eaten, and probably the public will in time cease to demand only white, or almost white, flour.

Fermentation; Leavening or Panification.—The idea of bread-raising by the fermentation of flour is very old; it is mentioned in the Bible. Fermentation may be broadly defined as a process whereby certain substances are produced by the growth of living cells, or by lifeless products of these cells called “enzymes;” the latter act in the presence or absence of the living plant or organism. The cells or enzymes are called the **ferment**, and the substance acted upon the **fermentable body**. **Fermentation, therefore, is a change induced where enzymes are the active cause.** The early history of fermentation is mainly concerned with *alcoholic* fermentation. (As will be briefly explained later, there are many other kinds, *e.g.*, *acetic*, *lactic*, *butyric*, and *diastatic* fermentations). Until the sixteenth century it was thought that alcohol was present before the fermentation started, but in combination with impurities, and that fermentation separated and removed these. It was then proved that sugar must be present, and that alcohol was absent before the fermentation commenced. About fifty years later it was noticed that “*budding*” took place of the very small spherical bodies in the sediment or scum of fermenting liquors. Then it was shown that fermentation, resulting in the formation of alcohol, was due to the actual growth of a plant or organism consisting of cells. **Liebig** offered strenuous opposition to this theory and tried to explain fermentation by physical and chemical laws

outside any action of life. The brilliant researches of **Pasteur** finally placed *alcoholic* and other *fermentations* into the category of changes induced by living cells, and thus the intensely interesting and wide subject of **bio-chemistry** was fully launched upon the scientific world.

Acetic fermentation is the conversion of alcohol into acetic acid (as vinegar) by the growth of green mould in beers or weak wines, with access of air. **Lactic fermentation** is the change of milk sugar into lactic acid, as when milk turns sour. **Butyric fermentation** is the result brought about by organisms, as when butter turns rancid. **Diastatic fermentation** is brought about by malt extract acting upon starch, with the production of dextrin or British gum, and a sugar called maltose. Until a comparatively few years ago a very sharp line of demarcation was drawn between different kinds of fermentation, *e.g.*, (1) those brought about by enzymes (such as the browning of cut potatoes and apples, and the liberation of prussic acid from bitter almonds), which went on apart from any cell structure, and (2) those induced by the growth of plant cells, such as the conversion of weak sugar solution into alcohol, etc., by means of yeast. Those belonging to the first class were called *unorganised*, and those to the second, *organised* ferments. This sharp distinction has, however, been found not to be justified. It has been clearly proved that alcoholic fermentation can be brought about by yeast juice entirely devoid of plant cells, so that this fermentation, which was always thought to be a change brought about purely by growth, must be due to enzyme action. It is quite likely that all kinds of fermentation will eventually be proved to be due to the lifeless, structureless enzymes, although this stage has not yet been reached. It is, of course, easier to have alcoholic fermentation with yeast cells, but the presence of the actual cells is not necessary. A better classification of ferments is into "*intracellular*" and "*extracellular*" ferments, denoting those which are dependent upon cell growth and

outside cell structure respectively. Enzymes must be looked upon as of the utmost importance to living cells; in fact, as the invisible chemical agents present in small quantities able to induce certain changes in a great mass of fermentable substance. Notable enzymes are the **oxydases** which operate only in presence of air (examples of these have already been referred to) and **diastase**, giving rise to the *diastatic* fermentation referred to in Wood's theory regarding strength of flour. After these introductory remarks, we shall now confine our attention to *alcoholic* fermentation as utilised in the rising of dough.

Yeast cells are about $\frac{1}{3000}$ in. in diameter, some being spherical, some oval, and others elongated (see Fig. 37). They are colourless under the microscope, but creamy white when in masses. They consist of a shell of woody fibre or cellulose encasing a mixture of protein, fat, and salts. These cells require food and favourable conditions for their development. This growth is known as "*budding*," and was first noticed in 1837, thus marking a very distinct advance in our knowledge of fermentation. The required food is absorbed through the cell wall, the requisite ingredients assimilated in correct quantities, and the waste products excreted. *The foods required for the development of yeast are* (a) *oxygen gas* either dissolved in the water used or derived from the decomposition of the sugar (bread dough ferments because it contains sugar and also because some sugar—maltose or malt sugar—is formed by the diastase present in the flour acting upon the starch), (b) *nitrogenous matter* (this is present in the dough), and (c) *mineral salts* such as potassium and magnesium phosphates. The *waste* products excreted by the yeast cells are *carbon dioxide* (a gas which distends the dough), *alcohol*, *succinic acid*, *glycerine* or *glycerol*, and *lactic acid*. *The average temperature required is 80° F.* At a low temperature development is checked. Above 100° F. the vitality

of the yeast is weakened, and at 212° F. is entirely non-existent. It is a great disadvantage to allow the temperature to vary, as the fermentation then proceeds too unevenly. Suppose we now perform the fermentation so as to examine and collect some of the products. Rather more elaborate

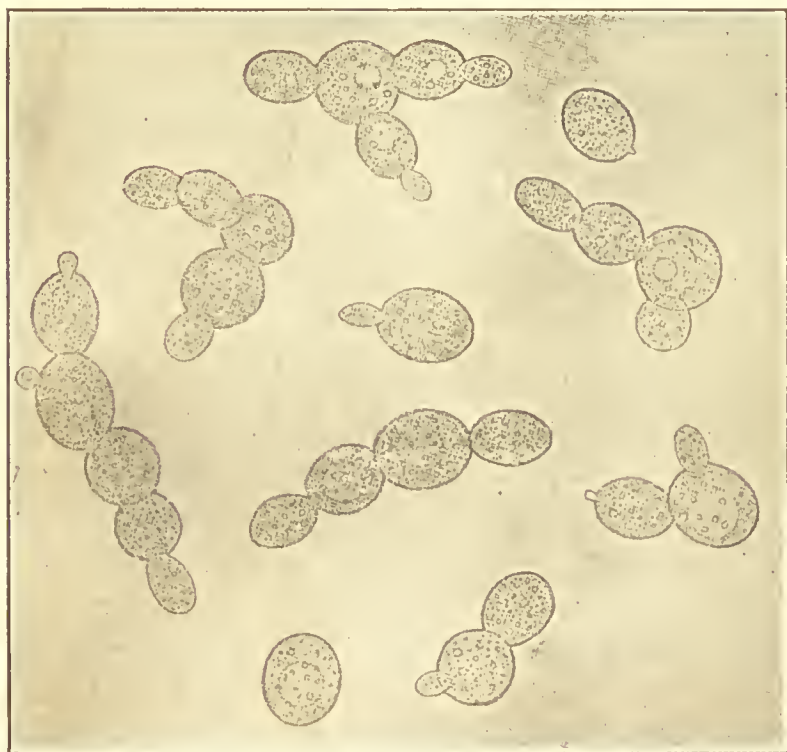


FIG. 37.—Yeast Cells (highly magnified).

apparatus will have to be employed now, and some description of the most important pieces will be given in the next chapter.

Expt. 86. Take a large flask and fit it up, as shown in Fig. 38, with an india-rubber stopper, a glass tube passing through one hole in it and bent down so as to dip into a

glass vessel. A thermometer passes through a second hole in the stopper and reaches very nearly to the bottom of the flask. Take about $\frac{1}{2}$ oz. of German yeast and cream it in a bowl with a little sugar. Now add lukewarm water (temperature 90° F.), stir, and sprinkle in a little flour. Then introduce the whole into the flask so that it is about half filled, and with the thermometer dipping into the mixture when the stopper is placed in position. Keep the contents of the flask as nearly as possible at 80° F. Pour

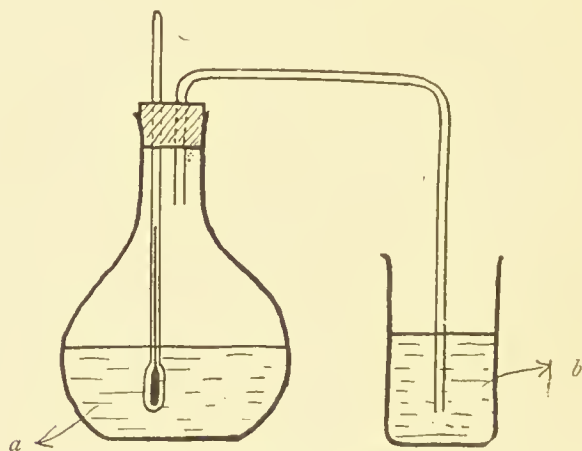


FIG. 38.—Alcoholic Fermentation.

a. Yeast, Sugar, Flour, and Water at 80° F. *b.* Lime Water.

a little clear lime water into the glass vessel "a," and have the glass delivery tube from the fermentation flask dipping into this. Before very long, bubbles of colourless, odourless gas will be seen passing through, and the lime water becomes turbid. This gas is carbon dioxide, and aerates the dough in bread-making. Even if there were no lime water to evidence the liberation of gas, the very frothy appearance inside the flask would at once cause one to suspect that gas was being generated. If possible, allow the fermentation to go on for 24 hours. At the end of that time the frothing will have subsided.

Expt. 87. Pour off the clear liquid into another vessel—a distillation flask—and connect up to a Liebig's condenser so as to distil some of the fluid (see Fig. 39). Now heat up over a small ring burner and wire gauze until it boils, and about $\frac{1}{3}$ of the fluid has distilled into the receiving flask or receiver. The temperature recorded by the thermometer passing through the neck of the flask will probably be about 170° to 180° F. Now add some lumps of quicklime to the flask, allow to stand for a day, and carefully pour off any remaining liquid. Again

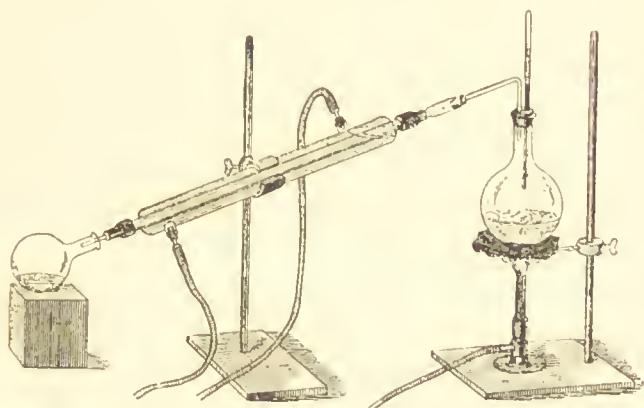


FIG 39.—Distillation of the Alcohol after Fermentation.

add some quicklime until it ceases to crumble away. Finally pour off the small quantity of liquid remaining. Smell it. It has a spirity, winey smell, and, on applying a light, burns with a pale blue flame like methylated spirit. **The substance is alcohol.** *Thus the production of two of the important substances generated in dough-raising, viz., carbon dioxide and alcohol, has now been demonstrated.*

Properties of Good Yeast.—It should first of all be pure throughout, *i.e.*, contain no moulds or putrefying organisms. It should also keep well and not turn sour quickly. Regularity and uniformity of quality should

be a feature of it rather than great fermentative power, although a combination of the two is desirable. A baker likes to know his yeast exactly, and what it will do. If not uniform in quality, this perfect understanding is impossible. Lastly, it should produce bread of good colour and flavour.

The Action of Yeast in Dough-Raising.—This is *not* merely one of *aeration*, as other methods of rising give other flavours. The *gluten* is softened and made more digestible. There is also a very characteristic flavour imparted, quite different from that obtained by other aeration methods. *Alcohol* is also produced in quantity, and *diastatic* fermentation proceeds, as the enzyme *diastase* is indigenous or native to wheaten flour, and some of the starch is changed to soluble *dextrin* and *maltose* or *malt sugar*. Hence the greater quantity of soluble ingredients in dough as compared with that in flour.

Dough Making with Yeast.—Almost everyone has her or his own method of making bread, and great surprise is often expressed at others' methods. Many add a little lard or butter; others—perhaps the majority—none. Again, some use a mash of boiled potatoes or potato water for adding to the flour. A potato mash furnishes a very lively fermentation.

The following are a few well-tried recipes for making the doughs specified :—

White Bread.—Mix 4 lbs. of flour and $2\frac{1}{2}$ teaspoonfuls of salt in a large bowl. Next take $2\frac{1}{2}$ teaspoonfuls of sugar and $1\frac{1}{4}$ ozs. of yeast, and cream them in a basin. Add water or thin boiled potato mash at 100° F. Make a cavity in the centre of the big bowl and stack up the flour all round. Pour the yeast mixture into the centre of the bowl, sprinkle over it a little flour, cover with a thick cloth, and allow to rise in a warm* place for twenty minutes, or until the

* It will have been noticed that in these recipes, where the words "put in a warm place" are used, the word "*warm*" has been asterisked.

surface of the "sponge" in the centre is quite cracked. Then knead thoroughly, adding the requisite quantity of tepid water (at about 90° F.). Cover again with a cloth

There is no more happy-go-lucky lack of method than in that concerned with the rising of dough. The bowl is placed near the fire, or in a warm room, and the regulation of the temperature left to chance. It is of the utmost importance that the fermentation should not receive a set-back by any marked lowering of temperature, as this acts detrimentally upon the

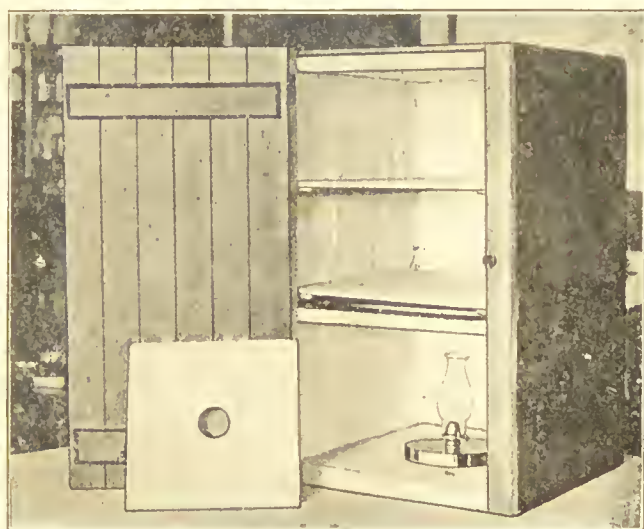


FIG. 40.—Cabinet for controlling the Temperature in Bread-making made out of a Packing Box.

quality of the resulting loaf. In the Ontario Agricultural College experiments with bread already referred to, a wooden box was used provided with three shelves and a door (see Fig. 40). The inside was lined with asbestos sheet to render it fire-proof and also to fill up cracks. A small lamp placed on the floor below the bottom shelf was quite sufficient to maintain a uniform temperature in the box when the door was closed. Of course a thermometer was hung inside so that the temperature could be observed at any time.

Such a box made out of an old packing case is strongly recommended, and is something one would like to see in every household where bread is made.

and allow to rise for two hours. The dough is then ready for making up into loaf form in the tins.

"Standard" Bread.—Use one and three-quarter pounds of 80% flour, $1\frac{3}{4}$ teaspoonfuls of salt, $\frac{1}{2}$ oz. of yeast, 1 teaspoonful of sugar, and 3 gills of tepid water at 100° F. Cream the yeast and sugar until fluid, and add 2 teaspoonfuls of flour and the tepid water. Cover with a cloth and set to rise in a warm* place for 20 minutes. Mix the flour and salt, pour in the yeast, and mix the dough, adding more tepid water if necessary. Knead until quite smooth, form into a loaf, and put into a greased and floured tin. Set to rise in a warm place until the loaf has doubled its size. It is then ready for baking.

Wholemeal Bread.—For making up wholemeal dough from "Artox" flour I found it necessary to use a little more yeast than in the above recipe for "Standard" bread, and also to have the dough much more wet and not so stiff.

Soda Bread.—Use two pounds of flour, 2 teaspoonfuls of sodium bicarbonate, 1 teaspoonful of salt. Mix up all the three ingredients, quickly make up into dough with very sour milk, and bake in a hot oven as soon as the dough is made.

Some Other Methods of Rising Dough—without Yeast.—Since aeration with gas is of primary importance, many methods have been devised for doing this. The addition of an acid to sodium carbonate or sodium bicarbonate at once generates carbon dioxide, so that if this carbonate is mixed with the flour and water added containing the requisite amount of acid, the dough is aerated by the gradually liberated gas. The use of hydrochloric acid results in salt being produced, so that not so much salt must be added to the flour to start with. *Baking powder*, which is essentially a solid mixture of sodium bicarbonate and

cream of tartar, only operates when made wet and carbon dioxide is again generated. The results are not so good in bread-making. **Self-raising flour** is simply flour and baking powder already mixed. Addition of water starts the liberation of carbon dioxide, and so the rising. In salt-rising bread a slack batter of milk and flour is allowed to stand at 100° F. until sour. This is then mixed with a "*sponge*" (prepared with hot water, flour and a little added salt), kneaded, and allowed to rise at the suitable temperature. This method gives uncertain results as the fermentation is brought about largely by chance invisible organisms from the air. A mash of new potatoes and water exposed to the air in a warm cabinet ferments in a day or two. This may be used for dough-making, but, as in the salt-rising method, the results are too uncertain to warrant recommendation. In *aerated* bread, carbon dioxide is used for the aeration without addition of the substances which generate the gas by inter-action. In all these cases, the taste of the bread is quite different from that where yeast is used.

We have now arrived at the stage where the dough is prepared and ready for the oven. As this baking means a brisk heating, it will be advisable to adopt analytical methods and first of all examine the action of heat on the various ingredients of the flour and dough. In this way we will be able to predict in a general way what will take place on baking. A very hot oven is required for bread-baking; usually a temperature of about 350° F.

What are the most important ingredients of flour? **Starch, gluten, and sugar**—the last more particularly in the dough.

Expt. 88. Starch is insoluble in cold water. Take some ordinary starch, powder it up, and then put into cold water. Stir. Allow to stand, and then carefully sieve the clear liquid through fine muslin resting on a funnel provided

with iron wire gauze at the top. Ordinary pure tap water on being evaporated leaves no appreciable residue. Evaporate to dryness some of the filtered water from the starch. There is no residue. Consequently starch will not dissolve in cold water. The solubility of starch in warm water might be tested.

The effect of heat on *Starch*.

Expt. 89. Take some more of the powdered starch, place in a saucer, and heat up in the oven to a temperature of 300° F., for about 1 hour. The oven used for the baking in Chap. III. will do excellently. Take out the saucer and examine what is now left. The starch has become yellowish-brown in colour. Add a little of this to cold water and stir. Filter, and evaporate the clear filtrate to dryness. There is a residue now, showing that the substance produced from starch on heating is soluble in cold water. It is called **dextrin**, or **British gum**, and starch altered in this way on being heated, whether partially or completely, is said to be *dextrinised*. At higher temperatures than 300° F., the colour of the substance becomes quite dark reddish-brown, and, added to water, imparts a similar distinct colour to it. The starch is now said to be *caramelised*. These two changes of *dextrinisation* and *caramelisation* will take place to some extent on baking. Finally, if starch is heated to a very high temperature, it blackens. This sometimes occurs when bread is burnt by being placed in too fierce an oven. *Dextrin* and *caramel* are soluble in cold water. Only about 4% of flour is soluble.

Expt. 90. It would be an interesting exercise to determine the amount of material dissolved out of bread by cold water and compare it with that dissolved from flour. Will the percentage be greater in the former case?

What is the action of heat on *sugar*? Most of the cane sugar used in making the dough will have been converted into alcohol and carbon dioxide. In any case,

however, a sugar is present (*vide* "Diastatic Fermentation").

Expt. 91. Heat up some cane sugar in the oven to a temperature of 292° F. It turns reddish-brown in colour and is now called **caramel**. This is used as a colouring for gravies. Dextrin and caramel are again referred to under "Toast" (p. 134).

Finally, with regard to *gluten*, the action of heat is to render it more readily attacked by the digestive juices. It is perhaps largely changed into a **peptone**, a soluble product into which proteins must be changed before they can be taken into the blood-stream as digested food. Heat does not alter the composition of *salt* in the least.

We are now ready to experiment and grasp what is involved in baking dough. A hot oven is required, especially at the start, but the temperature may be somewhat lowered later.

What are the most important changes which take place on baking? Firstly, is there any alteration in weight? So far, we have assumed that a hot oven is best at the start; all cookery books state the fact, and we have taken it for granted. Suppose we experiment, however, by (a) baking in an oven hot to start with, and (b) starting the baking in a cold oven, gradually making it hot enough.

Expt. 92. Example of experiment (a)—*Hot* oven to start with:—

	lbs.	ozs.
Weight of the baking tin used ... =	14	
" " " + dough =	3	3
\therefore the weight of dough used ... =	2	5
Weight of the loaf after baking for		
about 1 hour and cooling... ... =	2	1
\therefore the loss in weight =		4
And the percentage loss =	$\frac{4}{37}$	$\times 100 = 10.8$.

Expt. 93. Example of experiment (b)—alcohol, water and carbon dioxide—*Cold* oven to start with :—

	lbs.	ozs.
Weight of the baking tin used ... =	14	

" " " + dough =	3	6
-----------------	---	---

∴ the weight of dough used ... =	2	8
----------------------------------	---	---

Weight of the loaf after baking and

cooling =	2	4
------------------	---	---

∴ the loss in weight =	4	
-------------------------------	---	--

And the percentage loss =	$\frac{4}{40} \times 100 = 10.$
----------------------------------	---------------------------------

Evidently, then, a loss in weight results on baking, and there is very little difference, as far as the loss is concerned, whether the oven be hot or cold at the commencement. The loaf from (a), however, was of far better quality and texture, the loaf from (b) being sodden and "sad" in the centre; it did not quickly recover from the imprint of the finger. The advantage of the hot oven to start with, as recommended by all books, is thus proved. What can this loss of about 10% be? We know that we have added water in making the dough, and we have previously demonstrated the production of alcohol and carbon dioxide during the fermentative action involved in the dough-raising. To determine the nature of the loss we shall employ the same apparatus as was used to examine the products from baking meats, described and illustrated in Chap. III.

Expt. 94. Perform the experiment on the lines indicated in the example given below.

Example of Experiment of Baking Bread to Collect the Products Given Off.—The apparatus was fitted up exactly as for baking meat (see Fig. 19), the dough prepared, placed in its tin, and then introduced into the larger tin. The cover was then fixed on securely and the heating-up commenced. [This experiment of course corresponds with that of (b), *i.e.*, a *cold* oven to start with.] A Liebig's condenser (described in Chap. IX.) was

used to cool the products. Quite a quantity of liquid collected in "E," and the bottle "F" again became full of gas. On screwing up the clip "G" and disconnecting, at the end of the baking, the gas left in "F" was found to extinguish a lighted taper, and to turn lime water milky. It was carbon dioxide, or largely this gas, driven from the dough by heat. The liquid in "E" caused quicklime to slake, so that it contained water. A little spirity smelling liquid, which did not slake the quicklime, was left. This was alcohol. **The loss in weight then is made up largely of alcohol, water, and carbon dioxide.**

In the ordinary process of baking in the oven, these products are lost. The whole of the alcohol produced in the dough is, however, not driven off on baking; even stale bread contains as much as 33% of it; and, of course, all the water added in making the dough is not lost. How do we know this? Flour contains, perhaps, 13% of water, but fresh bread contains about 40%.

If the experiment of determining the amount of the cold water extract of bread has been carried out, it will have been found that a much greater proportion is soluble than in the case of flour. This means that the insoluble carbohydrate, or insoluble starch, has been largely changed into a soluble form, partly by the action of heat and partly by the operation of the indigenous enzyme in the flour during the dough-raising and before the baking. Certain acids (lactic, acetic, etc.) are also formed during the dough-raising, and a change takes place in the solubility of the gluten. If any lard or other fat is used in making the dough, a portion is partly converted into vapour and driven off as such. Starch is insoluble in water, because it is made up of a great number of exceedingly small cells with insoluble coats, but their contents are soluble. On baking, some of these cells are partially ruptured and disintegrated, and thus rendered more susceptible to attack by the digestive juices.

What are the essentials of successful bread-baking?

(1) *Good bread flour of good strength.* (2) *Uniform quality of yeast.* (3) *Dough of the correct consistency.* (4) *Exact control of the temperature at all stages, both in the preparation of the dough and in the baking.* (5) *To bear in mind that soft flour has not the expansive power of strong flour, and that the dough from soft flours must not be allowed to rise longer than is necessary; if it rises to the point of partial subsiding, the bread will not be so good.* (6) *To avoid the surface of the dough becoming dry and cracked; this causes dark streaks in the bread.*

What experiments may now be performed with the loaf itself? The crust is always of a yellowish colour, in parts quite brown—very different from the pale cream crumb, as it has been exposed to a higher temperature than the interior, and will therefore be more completely dextrinised, *i.e.*, converted into dextrin.

We shall experiment by determining (a) the amount of solid material in the crust and crumb respectively, and (b) the amount of crust and crumb soluble in water.

Expt. 95. Weighed quantities of crust and crumb are dried in tins placed over steam.

Example of experiment (a), to determine the percentage of solid material in the crust:—

	ozs.
Weight of the tin used for the drying	$= 2\frac{3}{4}$
" " " " + pulverised	
bread crust	$= 7\frac{3}{4}$
∴ the weight of crust used	$= 5$
Weight of the tin + dried crust when	
constant in weight	$= 6$
∴ the weight of dried residue	$= 3\frac{1}{4}$
And the percentage of solid material	$= \frac{3\frac{1}{4}}{5} \times 100 = 65.$

Example of experiment (*a*), to determine the percentage of solid material in the crumb:—

	OZS.
Weight of the tin used for the experiment =	3
" " " " + crumbs =	8
∴ the weight of crumbs used =	5
Weight of tin and crumbs after drying	
three days until constant in weight... =	6
∴ the weight of dried crumbs =	3
And the percentage of solid material =	$\frac{3}{5} \times 100 = 60$

These results are exactly what one would expect, as the crust of the loaf is exposed to a much higher temperature than the inside; consequently more water, alcohol, etc., are driven off.

Expt. 96. Proceed as indicated in the following.

Example of experiment (*b*) to determine the amounts of water-soluble ingredients in the crust and crumb respectively:—

Equal weights of crust and crumb are treated with warm water at the temperature of the body, *i.e.*, about 98° F. After stirring for ten minutes and thorough maceration, the two are allowed to stand undisturbed until quite settled. The clear extracts are then poured off and evaporated in weighed saucers. In a sample experiment slightly more residue was left from the extract of crust than from the crumb. Determine the exact amounts as an exercise. What is the scientific significance of this fact? That crusts, provided everything else is equal, contain a little more immediately usable or available food than the crumb of the bread, although there may be very little eventual difference of food value. Motherly and grandmotherly instructions about crust-eating are thus not entirely devoid of scientific truth.

Expt. 97. The aqueous extracts of crust and crumb may easily be tested for (1) *starch*, (2) *dextrin*, (3) *caramel*, by adding a little cold solution of iodine in water to some of each. A dark mahogany colour will be obtained with the crust, but a deep blue with the crumb extract; these are colour tests for dextrin and starch respectively. The extract from the crust is quite yellowish, showing the presence of a little caramel, whilst that from the crumb is colourless, denoting its absence.

Toast.—Very little need be said to explain what happens when bread is toasted. The surface of the cut slice of bread is raised to a higher temperature than it was during the baking process, and so much of the surface is not only dextrinised, but caramelised. If toasted at too high a temperature, blackening occurs. The following experiments on toast are suggested :—

Expt. 98. (1) Weigh bread before and after toasting, allowing the toast to cool before weighing; (2) determine the amount of lukewarm water soluble extract of toast and compare it with that of bread; and (3) test the extract of toast for starch or dextrin with iodine solution, and for caramel by gauging the amount of colour. Very little if any starch will be noticed, but plenty of dextrin and caramel. If the toasting of bread is carried out slowly, so that it becomes very hard, brittle and browned all through, as it is in the well-known “Zweiback,” practically all the starch is transformed into dextrin, and thus may be eaten with safety by patients forbidden to eat starch.

The Nutritive Values of Different Kinds of Bread.—The problem of the relative nutritive values of different kinds of bread has long been a subject of controversy, perhaps intensified by the introduction of the 80%.

"standard" bread. The different typical kinds of bread are **white**, **brown**, "**standard**," and **whole-meal**. Certainly the old views and contentions may have to be modified with regard to **Artox** whole-meal, which contains the whole of the wheat in what is probably its most digestible form.

The following are the main points in the controversy :

On paper the **whole-meal** and "**standard**" breads appear superior to the **white**, but many facts seriously modify the bare analysis figures. The stomach is scarcely a piece of chemical apparatus, and there is never complete assimilation and metabolism (a term denoting the changes that food undergoes before the waste products are ultimately eliminated from the system). For example **bran** is *theoretically* a rich food, but it is only in very exceptional cases used as food by human beings. The "**Artox**" millers claim that the sharp, spiky particles of the husk or spiculæ are treated so as to render them perfectly digestible and non-irritant. Perhaps, after all, no definite rule can be made with regard to the value of the different breads, because the personal factor comes so much into prominence. If **whole-meal**, **brown**, or "**standard**" breads are preferred to **white**, they are probably more beneficial ; if **white** bread is preferred, it is equally probable that white will be more nourishing. The influence of mind over appetite and digestion is so great that each case must be judged on its merits and not summed up in a general rule. Very rigid physiological and chemical tests have to be carried out involving the weighing of all food and excretions, and also the change of nerve energy. The settlement of the question is therefore one of great difficulty and many experiments have been performed by careful and authoritative workers in the United States of America. The composition of different kinds of bread, the weights of food constituents, the fuel value of each, and the digestibility and availability of the nutrients, as determined by them, are here given :—

COMPOSITION OF BREAD.

Kind of Flour	Mois- ture	Protein	Fat	Ash	Soluble Carbo- hydrates
Patent	36.80	7.60	1.80	1.25	52.53
Bakers' grade	36.84	7.82	1.71	1.32	52.30
Standard patent 85%	37.40	7.74	1.71	1.27	51.88
Bakers' bread	38.02	8.23	.43	1.13	51.63
Home-made					
Spring wheat	37.24	9.28	1.54	.92	51.04
Home-made					
Winter wheat	33.31	6.17	2.54	1.06	56.91

WEIGHT IN GRAMS¹ OF FOOD CONSTITUENTS AND FUEL
VALUE OF EACH LOAF OF BREAD.

	Protein	Fat	Carbo- hydrates	Ash	Fuel value
Patent	36.60	8.84	268.17	5.27	1399
Bakers'	37.39	8.65	267.22	6.68	1393
85% Manitoba	39.73	8.67	265.13	6.66	1388
85% Ontario	26.91	7.63	274.15	5.38	1351

¹ Divide by 28.34 to convert into ounces.DIGESTIBILITY OF NUTRIENTS AND AVAILABILITY OF
ENERGY OF BREAD.

	Protein %	Fat %	Carbo- hydrates %	Energy %
White Bread	85.8	56.4	97.5	90.1
Entire-wheat bread	80.4	55.6	94.1	85.5
Graham Bread	77.6	58.0	88.4	80.7

These figures are all in favour of white bread. Food for the body may be likened to coal for a fire—the greater the heat given out on burning in the latter case, the better the coal is, weight for weight. Similarly, the greater the fuel or heat value of a food, the better it is, because heat is continually required by the body to keep the blood warm. Just as a fire burns low or goes out through insufficiency or absence of coal, so life languishes and ceases if food is not taken in sufficient quantity and of requisite quality to supply heat to the body by its metabolism. The conclusions of Lawes and Gilbert were arrived at in 1857, before the steel roller process for grinding flour was in vogue, and are therefore perhaps all the more interesting. Put briefly, they are that (1) no definite opinion can be expressed from the theoretical text-book knowledge; (2) navvies, who have to perform much muscular work, prefer white bread; (3) owing to the aperient action of brown bread there may not be sufficient time for the nutriment to be extracted. Here, again, the “Artox” millers claim that although their bread prevents constipation, it has no irritating action on the stomach or intestines and the food is not unduly hastened through the system. In conclusion, the report of St. Bartholomew’s Hospital in 1897 may be briefly summarised:—(1) The higher *theoretical* value of brown bread, as apparent from the constituents, cannot be taken as reliable proof of its superiority. (2) White bread is, as a rule, weight for weight, more nutritious than brown. (3) In the cases of people with irritable intestines, white bread is to be preferred to brown. (4) For people with sluggish intestines, brown bread is preferable to white. (5) In cases where mineral ingredients (especially salts of calcium) in other articles of food or drink are deficient, brown is preferable to white. (6) If the dietary is deficient in fat, and if fat in other forms is not easily digested, brown bread may possibly be preferred to white. More exact

and definite information will be forthcoming, no doubt, after further careful physiologo-chemical inquiries amongst different types of individuals in various walks of life.

Adulteration of Flour and Bread.—The most commonly used adulterant, among a host of possible ones, is **Alum**. Flour may be tested for this as follows:—

Expt. 99. Take about 2 ozs. of flour and mix with 2 ozs. of pure or distilled water. Then add about $\frac{1}{6}$ oz. of a recently made solution of logwood chips containing a little rock ammonia or ammonium carbonate dissolved in it. If a *lavender-blue* colour is obtained instead of a *mahogany* colour, there is sufficient presumptive evidence of the presence of alum to warrant further investigation on lines which need not be gone into here. If blue colour is not obtained alum is absent, or present in negligible quantity.

Expt. 100. An alternative method is to soak a strip of gelatine in the cold extract of the flour for twelve hours, and then dip into the logwood solution prepared as mentioned before. If alum is present the gelatine becomes blue.

Expt. 101. Bread is tested in a similar manner, the crumbs being mixed up with water, and the gelatine soaked in this, as with the flour, for 12 hours. The use of alum in flour or bread is to be very much deprecated.

Brief reference has already been made to the report of J. McPhail regarding the addition of what he believes is calcium phosphate to weak flour. The result of this is to make a "*lofty*" white loaf containing a good deal of water, and, as a commercial result, it enhances the value of each bag of flour by about one shilling. The amount of phosphate powder added is $1\frac{1}{4}$ lbs. to a sack of 280 lbs. of flour, and this adulterant can be added and thoroughly mixed in ten minutes, without the knowledge of the workmen. The powder is sold to bakers to adulterate their loaves, and so

bring low grade flour into a high grade, as shown by chemical analysis. The method of detection is to run the flour through a very fine sieve, when the adulterant forms small lumps and is easily recognised by tasting. In McPhail's opinion the use of the adulterant should be most strictly forbidden.

QUESTIONS.

1. Why is it difficult to obtain a flour of one uniform quality?
2. Discuss the various circumstances affecting the growth and quality of wheat, particularly with regard to (*a*) the quantity of gluten in the grain, and (*b*) the quantity of starch.
3. Draw a section of a grain of wheat, pointing out the different portions of it. Which parts enter particularly into the composition of (*a*) whole-meal; (*b*) "standard," and (*c*) white flour?
4. What are the principal operations in the milling of flour? Explain what is meant by (*a*) stream; (*b*) grade; (*c*) semolina; (*d*) dunst.
5. What is the characteristic property of wheaten flour which renders it specially suitable for bread-making? To what is this property due?
6. A sample of white flour is provided. How would you determine the percentage of cold-water soluble material in it?
7. Why is the determination of the percentage of water in flour a matter of importance? How is the experiment carried out?
8. How would you separate starch and gluten from flour? Is it correct to say that white flour is almost all starch?
9. Discuss the various views which have been or are still held with regard to "strength" in flour, and the various theories propounded to account for it.
10. Three samples of white flour are provided. Arrange them in order of strength as regards (*a*) water absorption capacity; (*b*) weight; (*c*) size; (*d*) shapeliness, and (*e*) quality of bread producible from them.
11. One pound of white flour yields 1 lb. 3 ozs. of bread; 1 lb. of another white flour gives 1 lb. 6 ozs. of bread. How do the strengths of the flours compare with the recognised authoritative weak, medium-strength, or strong flours respectively?
12. Why is it faulty to accept either (*a*) the water absorptive capacity of a flour or (*b*) the weight of a loaf produced from it as sufficient indication of its strength and quality?
13. Two samples of white flour are given. Describe fully the different experiments you would perform to find out which is the better for bread making?

14. What is meant by (*a*) "blended"; (*b*) "hard," and (*c*) "soft" flour? Which is the best and worst for bread-baking purposes.

15. What is bleaching of flour, and why is this operation performed? Is it desirable in the public interest?

16. Explain clearly what is meant by (*a*) fermentation; (*b*) fermentable substance; (*c*) ferment; (*d*) enzyme. What particular fermentations take place in dough and bread-making?

17. Describe how you would carry out the experiment of alcoholic fermentation so as to demonstrate the production of the chief substances.

18. Write a short essay on yeast, mentioning particularly its essential qualities for successful bread-making.

19. What are the special actions of yeast during dough-raising?

20. Describe some of the devices in operation for making dough light without the action of yeast.

21. What are the essentials of successful home bread-making and baking? Why is it desirable to have the temperature constant during the rising of the dough? How can this uniformity be easily obtained?

22. Describe a good method for the preparation of dough using, (*a*) white; (*b*) "standard," and (*c*) whole-meal flours respectively?

23. What happens to (*a*) starch; (*b*) gluten; (*c*) sugar, on heating to the temperature required in bread-baking? Why is it useful or necessary to have this information prior to the examination of the bread itself?

24. A sample of bread, and the flour it is made from, are provided. Determine and compare the amounts of their cold-water soluble ingredients.

25. Describe the most important changes brought about by the baking operation. Sketch and describe an apparatus suitable for the collection of the volatile substances usually lost during this operation, and explain how would you examine them.

26. What are the most important changes which occur when bread goes stale? How would you determine the amount of cold water-soluble material in the crust and crumb of bread respectively? What experiments can be performed with these two aqueous extracts?

27. Why is the nutritive valuation of different kinds of bread a matter of great difficulty? What do you consider are the most important points to be borne in mind in such questions?

28. What adulterant of flour and bread is the one usually used whenever contamination takes place? How would you test for it in the two?

CHAPTER IX

Introduction to pure science—Matter : physical and chemical changes—Latent heat—Some pieces of apparatus used by the chemist—Properties of mixtures and compounds both of gases and solids—Elements and compounds—Symbols, formulæ, and equations—Inorganic and organic divisions of chemistry Alkalies, acids and salts—Preparation of and formulæ for salts

So far, common kitchen articles and utensils have been utilised as much as possible, and elaborate tests carefully avoided. This method has been adopted as a compromise, to meet the majority of domestic science students and the general public whose knowledge of pure science is limited. It is, however, very necessary that students should have a good grasp of the *fundamentals* of science, and the better this is, the more thorough will be the understanding and grip of the many difficult problems crowded within the domestic domain. An endeavour is made in this chapter to briefly present a few of the principles of physical and chemical science. These must be understood in order that what has been done and what is to follow may result in the maximum of benefit. This *pure science* has purposely been deferred until now so as to cause none to shrink from tackling the problems. If what has already been dealt with in as non-technical a manner as possible has been followed, the reader will be ready to study with interest the subject-matter of this and the remaining chapters of the book.

The science of chemistry concerns itself with the many changes in composition which **matter** may be caused to undergo. **Matter is anything perceivable by the senses of sight, touch, or smell.** It is not necessary that the form of matter be visible. Air cannot be seen, but it can be felt

when in motion as in a wind, and very often heard in this latter case. *Matter can exist in three different states:—* (1) *solid*, (2) *liquid*, (3) *gaseous* or *state of vapour*.

All *solids* have a certain definite shape which does not alter until external force is brought to bear upon them as, for example, in breaking something. They are composed of a great number of very small particles packed closely together and there is no innate tendency in them to change their shape. The force binding the particles of solids is called *coercive force* or *cohesion*.

In the *liquid* state the particles of the substance are not packed together at all, but, as a rule, move about among each other quite easily. Consequently liquids have no definite shape, but always assume that of the containing vessel.

Gases, unlike solids and liquids, possess no cohesion between the particles, or mere freedom of movement of them; on the contrary, the particles try to get away from each other as much as possible, with the result that gases always spread out and fill any vessel, no matter how large it may be. When a small amount of gas fills a large vessel the gas is said to be *rarefied*.

We have already referred to the great amount of heat required to merely change boiling water into steam, and the equally great amount given out on condensing steam to boiling water, *viz.*, the latent heat of steam. Have you ever wondered why it is that if one sits down in wet clothes or boots one very soon feels cold or catches cold? What happens in the case of rain ought surely to take place to some extent with any liquid, if the cooling effect on drying is a general principle.

Expt. 102. Pour a few drops of ether on the hand and wave it about. In a few seconds the ether has evaporated, *i.e.*, been converted into vapour. At the same time the hand feels quite cold. Evidently heat has been abstracted from the hand to change the liquid ether into

either vapour. This heat taken away or "absorbed" by liquids on evaporation is called "The latent heat of vaporisation." The liquid itself is not cold, but coolness results as the evaporation proceeds.

Again, why is it that the whole of a lump of ice does not melt *immediately* it is brought into a room that is at a higher temperature than the freezing point of water? Or why, when a sudden thaw occurs, does not the ice on a pond or lake immediately disappear, as by the wave of a magician's hand? Suppose we experiment.

Expt. 103. Take a piece of dry ice (which has previously been melting before being wiped dry), and, as quickly as possible, introduce it into a tin containing a weighed quantity of hot water and provided with a thermometer. Stir carefully until the whole of the ice is melted, observe the temperature, and weigh again. The increase in weight is that of the ice melted. Now take some crushed ice and surround with a little water until the latter registers 32°F . Empty the tin used for the first experiment and pour in the same weight of hot water as was employed before and at the same temperature. Place this on the spring balance and quickly add the ice-cold water (no ice) until the weight recorded is equal to the total weight before, *i.e.*, until as much ice-cold water has been added as the ice used in the first experiment. Stir until the temperature is uniform. Is the water now warmer or colder than with the ice?

Examples of experiments—(I):—

Weight of the empty tin used for the experiment	...	...	...	...	=	5
Weight of the empty tin used + hot water at 176° F.	...	...	...	...	=	13
∴ the weight of water at 176° F. used					=	8
A lump of dry ice (taken out of a mixture of it with water) was then						

introduced and the whole stirred lbs. ozs.
until the ice had disappeared. The
temperature was now 86° F.

Weight of the whole after the ice had
melted... .. = 1 $\frac{1}{2}$
 \therefore the weight of ice used = $3\frac{1}{2}$

(2)

Weight of the empty tin used for the
experiment = 5

Weight of the empty tin + water at
 176° F.... ' = 13

\therefore the weight of hot water used = 8

This was now placed on the balance
and ice-cold water quickly added
until the weight registered was = 1 $\frac{1}{2}$
(i.e., until $3\frac{1}{2}$ ozs. of ice-cold water
had been added.)

The temperature after stirring fell to 129° F.

• What can be gathered from these results? That ice-cold water (at 32°) does not lower the temperature of hot water so much as ice at 32° (cf. temperatures 129° and 86° F.) and this must be due to the fact that heat is required to merely change ice at the melting point into water at the freezing point. This heat is called the "Latent Heat of ice." Similarly, all solids require heat to merely melt them, i.e., in addition to that required to raise them to the melting point, and this heat is given out when they become solid again. These two amounts of heat are called "latent heat of fusion" and "latent heat of solidification" respectively. A freezing mixture of pulverised ice and salt is used for making ices, because both the ice and salt are changed into the liquid state; consequently so much heat is abstracted as to make a product cold enough to freeze water.

When these changes of melting, solidifying, evaporation and boiling, etc., are performed, no change in *composition*

of the solids ensues, since the substances started with can always be regained by a renewal of the old conditions. Such changes are called *physical*, *i.e.*, the operations only alter the arrangement of the particles of the substances amongst themselves. Experiments which result in alteration of the composition cause *chemical* changes.

Example of **chemical change** :—

Expt. 104. Place a piece of sulphur in an iron spoon and heat in the air; it melts and then bursts into a blue flame, which continues until all has disappeared. A pungent-smelling gas is noticed at the same time; a smell of burning sulphur. What has happened? The sulphur, as such, has disappeared, and no amount of cooling of the smelling gas will cause the solid sulphur to be re-formed, as it would if sulphur had been simply melted in a tin with the lid kept on loosely and then cooled. The burning of the sulphur is an example of a chemical change, as the gas produced is different in composition from the sulphur. One pound of solid sulphur will yield 1 lb. of melted sulphur, but 1 lb. of sulphur will produce 2 lbs. of the smelling gas. Many more examples might be given, but in every case there is a change in composition of the substance or substances started with.

Description of some Pieces of Apparatus.—The Bunsen Burner.—This is universally used in the laboratory for heating purposes (see Fig. 41). The principle is the same as in all ring burners and gas stoves. It is a simple arrangement for burning a mixture of air and coal gas in the air instead of coal gas alone in air, and for this reason is often called an “**Atmospheric burner.**” The coal gas issues from a small nozzle near the bottom of the burner, and precisely at that point is an arrangement for opening or closing one or two holes, or partially doing this, so that the onward rush of coal gas draws air in when the holes are open. On applying a light at

the top of the tube a blue flame is observed instead of the usual yellow smoky one. All Bunsen flames require a little knack in manipulating. Frequently gas stoves are disliked because they are not understood by the users. Often in turning a Bunsen flame low the flame

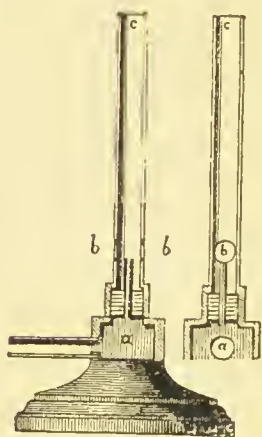


FIG. 41.—The Bunsen Burner.

a, gas jet ; *c*, tube surrounding the jet ; *b*, marks the positions of the openings in the tube for the admission of air.

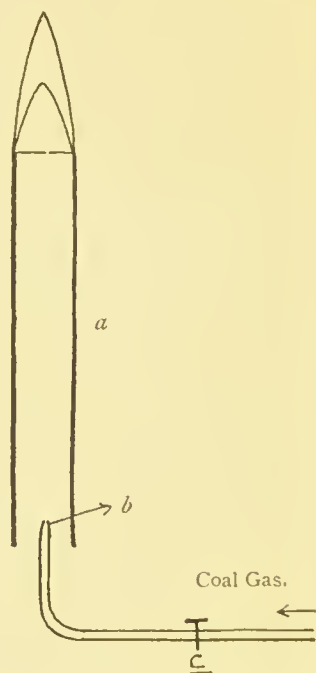


FIG. 41A.—Glass Model to illustrate the action of the Bunsen Burner.

suddenly "*strikes back*" with a pop and burns at the nozzle with a disagreeably-smelling, peculiarly-coloured, long, thin flame. "Striking back" can be avoided by first of all partially shutting off the air supply at the air holes, then lowering the flame, and re-admitting a little air very carefully until the flame is again all blue. An alternative method is to turn the gas on full while burning in this

wrong manner and then suddenly chop the india-rubber pipe with the edge of the hand, being careful to only momentarily have the hand in contact with the tube. In the case of a gas stove the only remedy for "*burning low*" or "*striking back*" is to turn the gas out and re-light after a few seconds, turning the gas on full. The following glass model of a Bunsen burner is very instructive (see Fig. 41A):—

Expt. 105. The wide glass tube " α " corresponds to the metal pipe of the burner, and the small glass tube with a

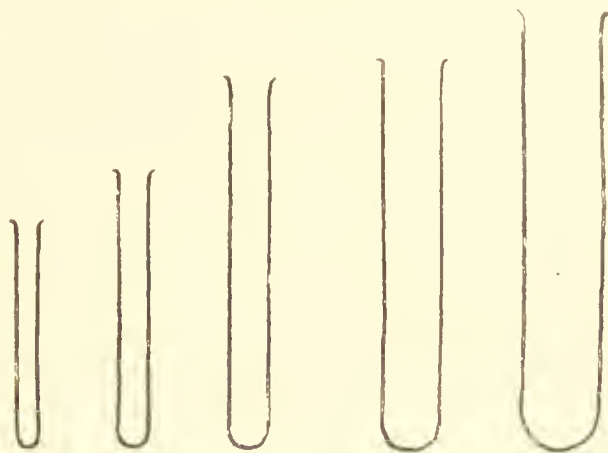
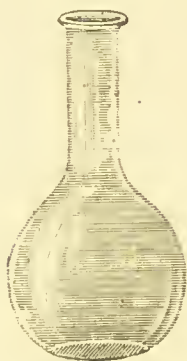


FIG. 42.—Test-tubes of different sizes.

nozzle at " b " is where the gas passes along. The rubber tube connecting this to the gas tap is provided with a screw clip " c "; the gas tap is turned on full all the time, and the supply of gas regulated by screwing or unscrewing the clip to different extents. The air space round the nozzle at " b " corresponds to the air holes of the Bunsen burner. Unscrew the clip " c " fully, and apply a light at the top of the glass tube " α "; the Bunsen flame is obtained. Now carefully close up the air space with the hand; the flame becomes the ordinary yellow one. Remove the hand and

turn the gas low by screwing up the clip; the flame will suddenly burn low at "b." Turn the gas on full again, chop the rubber tube smartly and the Bunsen flame will be again produced at the top of "a."



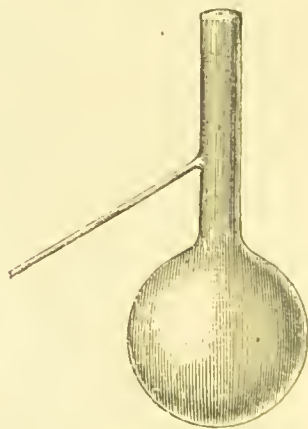
Florence Flask.



Erlenmeyer or Conical Flask.



Boiling Flasks.



Distillation Flask.

FIG. 43.

Test-tube.—A thin glass vessel, cylindrical in shape, closed and rounded off at one end and slightly bevelled at the other (see Fig. 42). They are made in different sizes, and the glass is such that the tubes may be heated to a very high temperature in the Bunsen flame without

breaking. They are used for heating solids, liquids, fluids or solutions, on a small scale or for small tests; hence the term "test-tube."

Flask.—This is another glass apparatus of various shapes (see Fig. 43) for heating up liquids or solutions, and, being provided with a narrow neck, any substance given off may be collected in a suitable manner from the top of that neck.

Beaker.—Almost like a thin tumbler (see Fig. 44) made of annealed glass to stand heating up with water, other

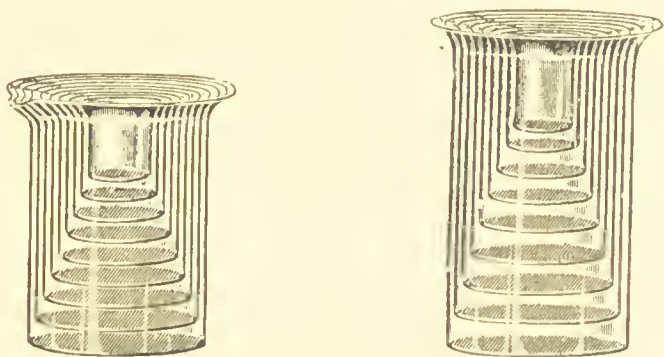


FIG. 44.—Beakers of Bohemian Glass (in nests).

liquids, or solutions. Beakers must not be heated dry with nothing in; nor must a liquid or a solution be evaporated to dryness in them.

Filter Funnel.—A glass funnel (see Fig. 45) used for making muddy liquids clear where the lack of clarity is due to floating or suspended solid particles of a substance. A circular piece of filter paper (like thin blotting paper) is folded into four (see Fig. 45), fitted into the funnel, moistened with water, and then the muddy fluid passed through. All particles of the foreign substance stay on the filter paper. This operation is called *filtration*, and has been performed hitherto in our experiments by passing through fine muslin.

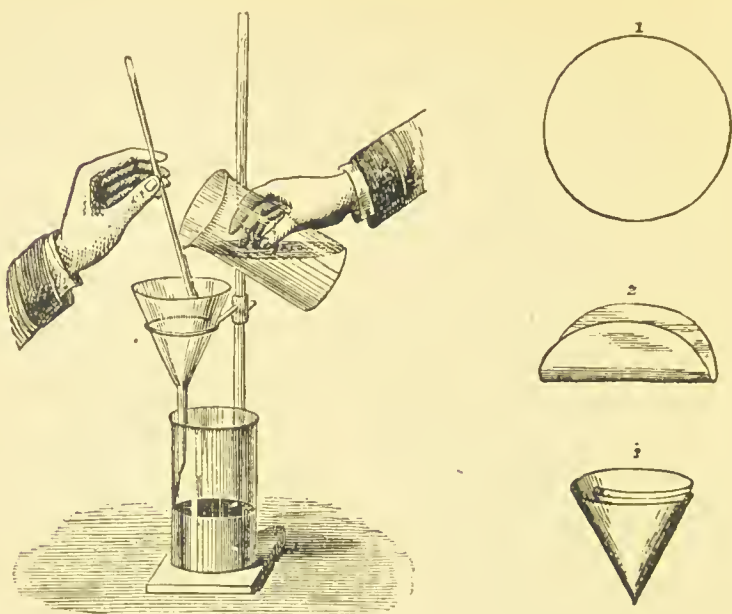


FIG. 45.

Filter Stand.—A wooden arrangement for supporting one or more funnels (see Fig. 46).

Wash-bottle.—A flask provided with a good-fitting rubber stopper and glass tubes as shown in the figure (see Fig. 47). Blowing at the uppermost end of the glass tube delivers a thin stream of water or other liquid through the nozzle.

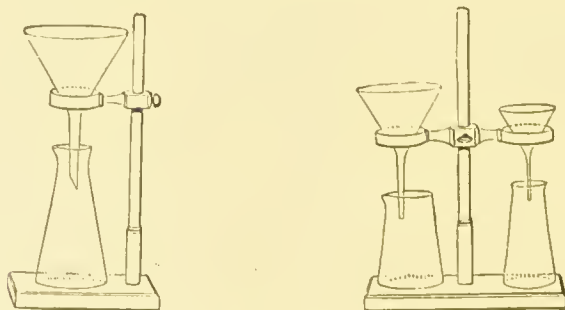


FIG. 46.—Filter Stands for one or two Funnels.

Woulffe's Bottle.—A thick glass apparatus, not made to stand heating in the flame, usually provided with two or three short necks (see Fig. 48).

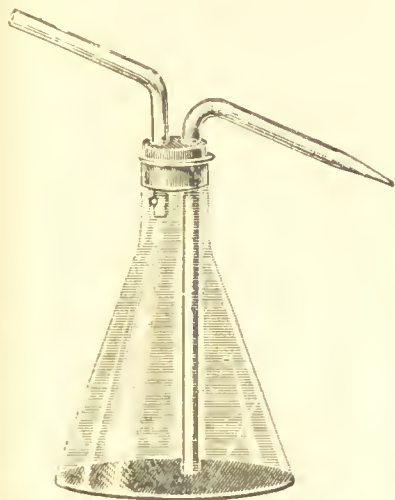


FIG. 47.—Wash-bottle.



FIG. 48.—Two and Three-necked Woulffe's Bottles.

Liebig's Condenser.—A glass arrangement for circulating cool water through a cylinder encasing an inner tube. Vapours or steam pass through the inside of the latter.



FIG. 49.—Liebig's Condenser.

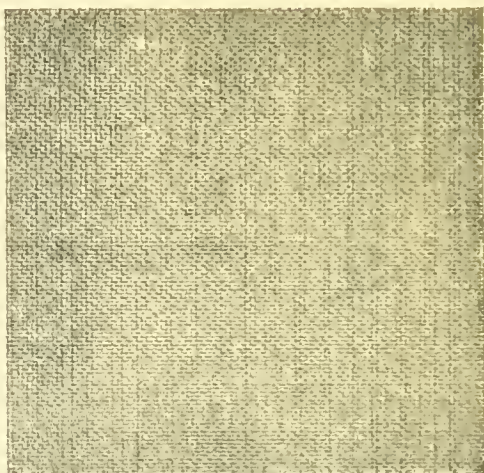
The cooling effect of the circulating cold water condenses the steam or condensible vapour, and this liquid drips from the end of the inner tube (see Fig. 49).

Tripod Stand and Wire Gauze.—The former is a three-legged iron support (see Fig. 50) to use with a piece of iron wire gauze (placed on the top of the tripod) for

heating a vessel with the Bunsen flame. Except in the case of a test-tube, all glass vessels which will stand heat-



Tripods.



Wire Gauze.

FIG. 50.

ing must be placed on the gauze and tripod, or gauze and some other convenient iron support.

Porcelain Dish (see Fig. 51).—Like a deep thin saucer, capable of being made very hot with the naked flame with-

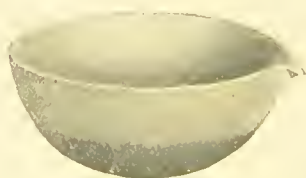


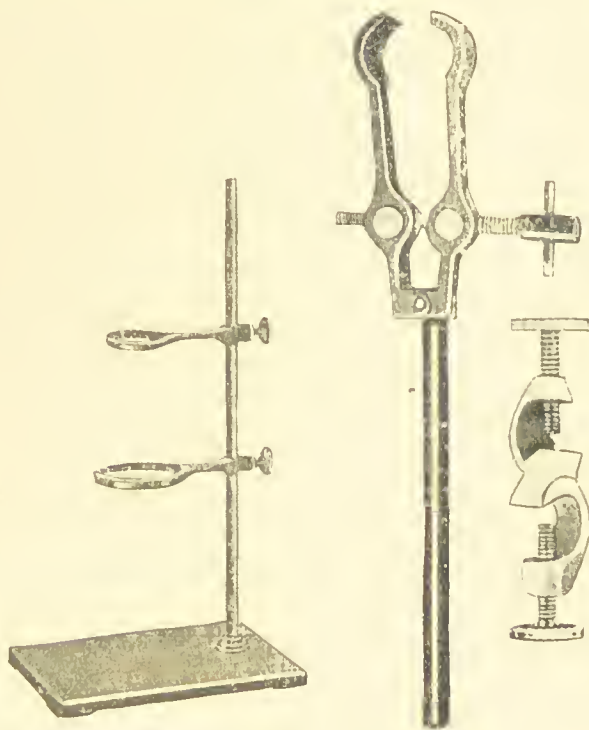
FIG. 51.—Porcelain Dish or Basin.

out breaking. It must not, however, be suddenly cooled with cold water or it will break.

Retort Stand, Clamp, and Boss (see Fig. 52).—Iron or brass arrangements for supporting and holding any piece

of apparatus in a desired position. The jaws of the clamp are lined with cork so that a good grip of a glass apparatus may be obtained without any risk of breaking it.

Burette and Stand.—The burette has already been described (see Fig. 31). This is held in a vertical position on a suitable stand.



Retort Stand and Rings.

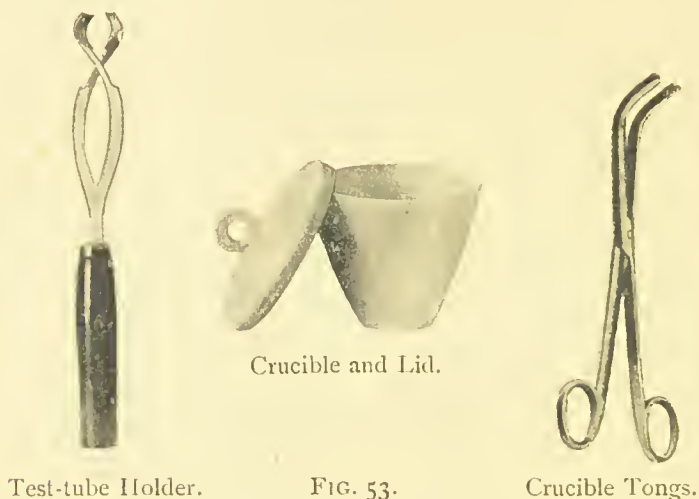
Clamp and Boss.

FIG. 52.

Test-tube Holder.—A wooden or metal arrangement for holding a test-tube when the latter becomes too hot to hold in the hand (see Fig. 53).

Crucible and Lid.—A small thin porcelain pot provided with a lid, and which will stand heating to a high temperature, but not sudden changes of the same (see Fig. 53).

Crucible Tongs.—A pair of metal tongs used for lifting the crucible or lid or other pieces of apparatus while hot (see Fig. 53).



Test-tube Holder.

FIG. 53.

Crucible Tongs.

Mixtures of Gases and Their Properties.—There are many gases, but all are alike in that they are made up of exceedingly small mutually repellent particles. Three of the most important are called Oxygen, Nitrogen, and Hydrogen. If, say, oxygen and nitrogen are mixed, is it possible to work out or predict the properties of the mixture? It is. Can they be separated again without alteration of temperature? They can. **In a mixture of gases** (1) *the properties are exactly what one would expect them to be, knowing the properties of the constituent gases and bearing in mind the proportions taken*; (2) *if the different gases are mixed at one and the same temperature, the mixture has that temperature*; (3) *the original gases can always be re-obtained by performing only physical experiments with the mixture*; (4) *any proportions may be mixed*. One example of a mixture will suffice,

viz., the air. The two most important gases in air, and their proportions, are roughly $\frac{1}{5}$ oxygen and $\frac{4}{5}$ nitrogen. Suppose we tabulate in columns the properties of oxygen and nitrogen, and work out the properties of air.

Oxygen.	Nitrogen.	Air. (Approximately.)
Colourless, odourless, tasteless gas.	Colourless, odourless, tasteless gas.	\therefore Air is ditto.
Scarcely dissolved by water.	Scarcely dissolved by water.	\therefore Air is ditto.
Specific gravity 16 as against hydrogen 1.	Specific gravity 14 as against hydrogen 1.	\therefore Specific gravity of air = $\frac{(1 \times 16) + (4 \times 14)}{5}$ = 14.4.
Rekindles a glowing chip.	Puts out a light.	Does not rekindle a glowing chip, but a light continues.

In all other properties those of the air can be worked out or predicted from those of the two constituent gases.

Compounds of Gases and their Properties.—If hydrogen and oxygen are mixed in the proportion of two volumes of the first to one of the second and a light is applied, a violent explosion occurs; the gases as such disappear, and only a few drops of water are formed, even if a pint of the gaseous mixture is taken. The water contains the two gases, *but in an entirely different condition from the two in the air*. The hydrogen and oxygen have united, a *chemical* action has taken place, and a **chemical compound** has been formed. The resulting substance has properties entirely its own, and different from those of either of the constituents. Who could predict that water is composed of two gases? **Oxygen and hydrogen in water are combined, and not mixed.** Suppose we tabulate the properties of hydrogen and oxygen and also those of water, and see the great contrast between the last substance and either of the other two.

Hydrogen.	Oxygen.	Water.
Colourless, odourless, tasteless.	Colourless, odourless, tasteless.	Colourless (?), odourless, tasteless.
Gas.	Gas.	Liquid.
Two volumes.	One volume.	Volume almost negligible as against the three volumes of the gases.
Burns with a pale blue flame.	Rekindles a glowing chip.	Does not burn and extinguishes a glowing chip.

As a rule, a "compound" of gases bears only accidental resemblance to any of the gases of which it is composed, and definite volumes are required to form the compound instead of *any* proportions as in the case of a mixture. When it is said that air contains oxygen and nitrogen it must always be remembered that they are present in the *free* state; but when one says that a protein contains nitrogen it must be borne in mind that the latter does not exist *free* as a gas in the protein, but *combined* and *unrecognisable*.

Mixtures of Solids and their Properties.—As in the case of gases, a mixture of solids resembles the ingredients of which it is composed, due regard being given to the proportions of each present; or the properties of a mixture of solids are the *means* of those of its constituents. Any number of ingredients and any amounts of them may be taken. The properties of the mixture may be worked out perfectly. Here is an example:—

Iron Powder.	Sulphur Powder.	Mixture of Iron and Sulphur.
Dark grey in colour.	Pale yellow in colour.	Colour between the two.
Say one part by weight taken.	One part by weight taken.	Two parts of the mixture.
Dissolves, disappearing apparently, in weak "spirit of salt."	Does not dissolve in weak "spirit of salt."	Half of it dissolves in weak "spirit of salt."
Insoluble in the liquid called carbon disulphide.	Soluble in carbon disulphide.	One half of it soluble in this liquid.
Suppose the average size of the particles is represented by 2.	Suppose the average size of the particles is represented by 1.	The average size of the particles of the mixture is $1\frac{1}{2}$.
Attracted by a magnet.	Not attracted by a magnet.	Half of it attracted by a magnet.

Compounds of Solids and their Properties.—Compounds of solids are composed of the ingredients united in certain definite (and not indefinite) proportions, and such that the constituents cannot be recognised at sight. The properties of the compound bear, as a rule, no resemblance to the properties of the constituents. *E.g.*, suppose we take the case of iron and sulphur as above.

Expt. 106. Heat the mixture in a test-tube; it soon starts glowing in one part and then quickly becomes red-hot through the whole mass. If the proportions taken are not exactly 56 of iron to 32 of sulphur or in that proportion, *e.g.*, 56 to 32, 14 to 8, or $1\frac{3}{4}$ to 1 some of one or the other will not be required. The material formed in the test-tube is almost black, is insoluble in carbon disulphide, is not attracted by a magnet, and dissolves completely in spirit of salt, giving off a gas smelling of rotten eggs. *This compound formed from the two, resembles neither iron nor sulphur.* To sum up: 88 parts of iron and sulphur mixture consist of 56 of iron and 32 of sulphur; $\frac{56}{88}$ of this dissolve in weak "spirit of salt"; $\frac{32}{88}$ of it in carbon disulphide; $\frac{56}{88}$ of it are attracted by a magnet and so on. Eighty-eight parts of the compound of iron and sulphur contain 56 of iron and 32 of sulphur, but *none* of it dissolves in carbon sulphide, *none* is attracted by a magnet, and the *whole* of it dissolves in weak "spirit of salt," giving off the bad smelling gas as before mentioned.

All solid compounds are composed of different substances combined in certain fixed proportions. Some of the constituents are solids, others gases. In all cases they are unrecognisable, judging from the appearance of the compound, *e.g.*, starch contains a solid called carbon and two gases—oxygen and hydrogen. Proteins contain the solids carbon, sulphur, and sometimes phosphorus, and the gases oxygen, hydrogen, and nitrogen. Fats contain

solid carbon, and gaseous oxygen and hydrogen. Common salt contains a peculiar, soft, solid metal, sodium, and a gas, chlorine. *In all cases, one is unaware of the presence of the particular constituents when judging merely by the appearance of the compound.*

Elements.—A substance which is incapable of yielding anything simpler in composition is said to be an element. Oxygen, hydrogen, nitrogen and chlorine are examples of gaseous elements; carbon, sulphur, phosphorus, sodium, and potassium of solid elements. For the sake of illustration, if 100 parts of sulphur by weight are considered they cannot be made to yield, say, 50 parts each or any other proportion adding up to 100, of two other substances differing from sulphur in composition. One hundred parts of sulphur may easily yield something else differing in composition, but in this case, greater in weight, and not simple, as sulphur is.

Compounds.—Compounds are composed of two or more elements united in certain definite proportions, which vary according to the particular compound. As stated above, the individual elements in a compound are not discernible. Water is a compound of 2 parts of hydrogen and 16 parts of oxygen by weight in 18 of the compound; common salt is made up of 23 parts of sodium and 35.5 parts of chlorine in 58.5 of the compound.

Symbols.—In order to write down an element in a kind of shorthand way, a **symbol** is used. In some cases this is the first letter of the word, but where confusion would arise by having two symbols the same, the first and some subsequent letter is used to provide adequate distinction. Again, in other cases the symbol is derived from the Latin name of the element.

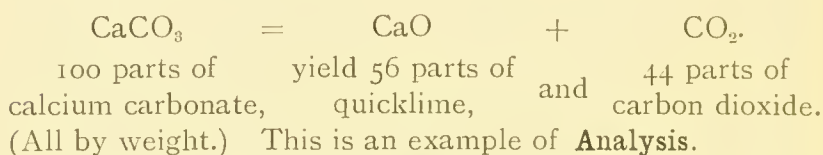
Examples :—

Element.		Symbol.
	(Capital letter if one ; capital and small if two.)	
Hydrogen	...	H.
Oxygen	...	O.
Nitrogen	...	N.
Carbon	...	C.
Sulphur	...	S.
Phosphorus	...	P.
Chlorine	...	Cl.
Potassium	...	K (from Latin Kalium).
Sodium	...	Na („ „ Natrium).
Silver	...	Ag („ „ Argentum).
Gold	...	Au („ „ Aurum).

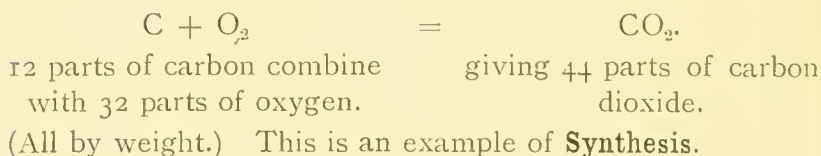
Not only is the name of the element expressed by the symbol, but a certain specific weight of it also, *e.g.*, H denotes 1 part by weight of hydrogen ; O, 16 of oxygen ; N, 14 of nitrogen ; C, 12 of carbon ; S, 32 of sulphur ; P, 31 of phosphorus ; Cl, 35.5 of chlorine ; K, 39 of potassium ; Na, 23 of sodium ; Ag, 108 of silver, and so on.

Formulae.—A compound is composed of two or more elements united in certain fixed proportions. **The shorthand method of representing this is by means of a formula, which is made up of the symbols of the elements, in correct proportions, placed alongside, *e.g.*, NaCl is the formula for common salt composed of 23 parts of sodium and 35.5 parts of chlorine ; H₂O the formula of water composed of 2 parts of hydrogen and 16 of oxygen ; HCl the formula for hydrochloric acid gas made up of 1 part of hydrogen and 35.5 of chlorine ; H₂SO₄ the formula for sulphuric acid or oil of vitriol made up of 2 parts of hydrogen, 32 of sulphur and 4 × 16 = 64 parts of oxygen. All these weights are in the proportions of the weights of the various elements building up the respective compounds.**

Analysis.—When a compound is resolved into two or more necessarily simpler substances it is said to be analysed, and the operation bringing this about is called **Analysis**. On the other hand, if something is built up from other substances **Synthesis** has been performed. These are examples of chemical change, and to express them and others fully, and yet in a shorthand way, a *chemical equation* is employed, *e.g.*, when any form of pure calcium carbonate is strongly heated it is resolved into quicklime and carbon dioxide gas; 100 parts of the carbonate yield 56 parts of quicklime and 44 parts of carbon dioxide. All these facts are expressed in the equation

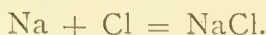


Carbon unites with oxygen to form carbon dioxide, *i.e.* :—



Some Types of Chemical Changes.—

(1) Union of Elements.

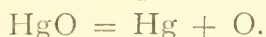


23 parts of sodium unite with 35.5 parts of chlorine giving 58.5 parts of sodium chloride, *i.e.*, common salt.

(2) Union of Compounds.



17 parts of ammonia unite with 36.5 parts of hydrochloric acid gas giving 53.5 parts of ammonium chloride or sal ammoniac.

(3) **Decomposition of a Compound into Elements.**

216 parts of mercuric oxide give 200 parts of mercury and 16 parts of oxygen.

(4) **Decomposition of a Compound into Simpler Compounds**
(already considered).(5) **Double Decomposition and Precipitation of One Substance.**

Na_2CO_3	+	CaCl_2	=	CaCO_3	+	2 NaCl .
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106 parts of sodium carbonate dissolved in water, added to 111 parts of calcium chloride also dissolved in water, give 100 parts of precipitated calcium carbonate and 117 parts of common salt remaining in solution.

Alkalies are substances which (1) dissolve in water; (2) affect the colour of certain pigments or indicators, *e.g.*, turn red litmus blue and pink methyl orange, yellow; (3) have a soapy taste and feel when in weak solution, but cause burning when strong; (4) absorb carbon dioxide so that the gas disappears as such, and cannot be regained without performing a chemical change; (5) do not effervesce with an acid unless they have been exposed to the air for a long time; and (6) whose formulæ (with the single exception of ammonia gas) terminate in a certain number of O or OH. N.B.—All of these properties must be exhibited before one can be quite sure that a certain substance is an alkali. The chief alkalies are:—

Caustic soda, formula NaOH .

Caustic potash, „ KOH .

Quicklime, „ CaO .

Ammonia gas, „ NH_3 , or ammonia solution, NH_4OH .

Acids are substances which, as a rule, (1) turn blue litmus solution red and yellow methyl orange, pink; (2) have a sour taste in weak solution, but corrode when strong; (3) liberate carbon dioxide from carbonates, such as calcium carbonate, with vigorous effervescence; (4) do not impart a decided colour to the Bunsen flame (except boric acid); and (5) react with alkalies to form substances called **salts**; this action is a mutual one, and it can equally well be said that alkalies react with acids forming salts. Some acids possess the fifth property only, and not the other four.

There are two broad divisions of compounds in chemistry, viz., **inorganic** and **organic**. Most inorganic compounds *do not* contain the elements carbon and hydrogen *together* in the one compound; organic compounds *generally do contain them, at least*. Consequently there are inorganic and organic acids. Some organic compounds react with acids to form salts; these are called **Organic bases**. Thus we have inorganic and organic acids, bases, and salts.

Hydrochloric	}	acids are inorganic (or mineral) and contain no C and H together.
Sulphuric		
Nitric		
Citric	}	acids are organic and contain C, H and also O.
Malic		
Tartaric		
Caustic soda ¹	}	are inorganic bases and contain no C and H together.
Potash ¹		
Ammonia ¹		

Glycerine is an organic base and contains C, H, and also O.

Formation and Preparation of Salts.—Salts are produced by the mutual reaction between alkalies (and all

¹ Alkalies are also bases, but as they dissolve in water, unlike the majority of bases, they receive this special name.

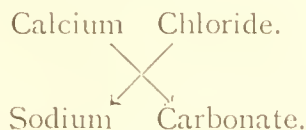
bases) and acids. They may, however, be prepared by the following additional methods:—

(1) **The direct union of the elements**, *e.g.*, the union of sodium and chlorine to form common salt.

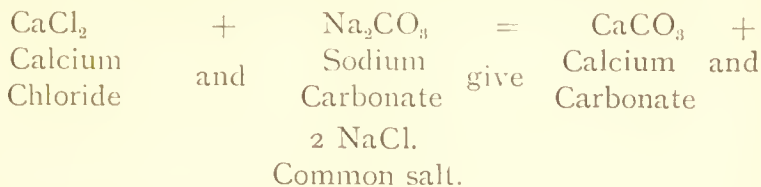
(2) **By pouring an acid on a metal**. There is a visible action (as a general rule; one or two exceptions), *e.g.*, zinc sulphate from zinc and weak sulphuric acid.

(3) **By double decomposition and precipitation**. This is an exceedingly valuable method for preparing a salt which is insoluble in water. *E.g.*, suppose we require to make calcium carbonate. It is insoluble in water.

Expt. 107. Take a solution of calcium chloride and add to it sodium carbonate solution



They, so to speak, exchange partners; one is precipitated, the calcium carbonate, and the other remains dissolved.



Nomenclature of Salts:—

All carbonates have been formed from carbonic acid or another carbonate.

All sulphates have been formed from sulphuric acid or another sulphate.

All nitrates have been formed from nitric acid or another nitrate.

All chlorides have been formed from hydrochloric acid or another chloride.

All **phosphates** have been formed from **phosphoric acid** or another **phosphate**.

All **borates** have been formed from **boric acid** or another **borate**.

Formulae of Salts:—

All **carbonates** must contain the group CO_3 a certain number of times.

All **sulphates** must contain the group SO_4 a certain number of times.

All **nitrates** must contain the group NO_3 a certain number of times.

All **chlorides** must contain the group Cl a certain number of times.

All **phosphates** must contain the group PO_4 a certain number of times.

All **borates** must contain the group B_4O_7 a certain number of times.

All **bicarbonates** must contain the group HCO_3 a certain number of times.

How many times, however? Refer to the following table:—

Column 1.	Column 2.	Column 3.	Column 4.
H	Ca (Calcium)	N	C
Cl	Sr (Strontium)	PO_4	
Ag (Silver)	Ba		
Na	Mg (Magnesium)		
K	CO_3		
NO_3	SO_4		
NH_4 (Ammonium)	B_4O_7		
OH			
HCO_3			

Any in column 1 may theoretically combine with any other in column 1, and similarly for columns 2 and 3. But any one in column 2 may combine with twice the amount in column 1 as given in the list; column 3, three times column 1, and so on.

E.g., the formula for **sodium chloride** is **NaCl** (both Na and Cl are in column 1).

„ „ **sodium bicarbonate** is **NaHCO₃** (both Na and HCO₃ are in column 1).

„ „ **ammonium chloride** is **NH₄Cl** (both NH₄ and Cl are in column 1).

„ „ **calcium carbonate** is **CaCO₃** (both Ca and CO₃ are in column 2).

„ „ **calcium bicarbonate** is **Ca(HCO₃)₂** (Ca is in column 2; HCO₃ in column 1).

„ „ **calcium sulphate** is **CaSO₄** (both Ca and SO₄ are in column 2).

„ „ **calcium chloride** is **CaCl₂** (Ca is in column 2 and Cl in column 1).

„ „ **Borax** (sodium borate) is **Na₂B₄O₇** (Na is in column 1 and B₄O₇ in column 2).

The groups NH₄, CO₃, SO₄, HCO₃, etc., do not exist in the free state, but only in chemical combination. They cannot be bought, sold, isolated, or kept.

Formulæ of a Few Compounds not Salts:—

Ammonia gas, **NH₃** (N is in column 3; H in column 1).

Hydrochloric acid, **HCl** (H and Cl are both in column 1).

Sulphuric „ **H₂SO₄** (H is in column 1 and SO₄ in column 2).

QUESTIONS.

1. What is matter? Describe the principal properties of the solid, liquid, and gaseous forms of it.

2. Describe what happens, or is likely to happen, in the following cases :—(a) a little ether is poured on the hand ; (b) some water is poured into a saucer and weighed every 12 hours ; (c) a child becomes wet through and sits down to dry ; (d) violent exercise is performed with little or no perspiration ; (e) violent exercise with profuse perspiration.

3. What is meant by the latent heat of ice? Describe an experiment to prove that your statement is correct. Is any use made of latent heat of fusion in domestic science?

4. What are physical and chemical changes and the differences between them? Give examples.

5. Describe with sketch the Bunsen or Atmospheric burner, and the various points to be observed to ensure successful working. What is "striking-back" or "burning low," and how can it be avoided?

6. It is required to perform the following operations ; (a) heat a little salt strongly ; (b) quickly evaporate a solution of salt to dryness ; (c) condense the steam from boiling water ; (d) take hold of a hot porcelain dish.

What pieces of apparatus would you employ to carry these out efficiently?

7. What are the most important properties of, and differences between, gaseous mixtures and gaseous compounds? One volume of oxygen is mixed with 2 volumes of nitrogen, both at 16° C. Enumerate the properties of the mixture, availing yourself of the properties of these gases given in the chapter.

8. Water is said to contain oxygen and hydrogen ; air, oxygen and nitrogen. Explain clearly what is meant by these statements.

9. Two parts of iron powder and 3 parts of sulphur powder are mixed. What will be the properties of the mixture? Refer to the chapter for the properties of the individual substances.

10. Explain symbol, formula, element, compound, and chemical equation. Give examples of each.

11. Common salt is said to contain chlorine ; a protein, nitrogen ; a fat, carbon and hydrogen. Why are these elements not visible or recognisable in the substances?

12. Explain the terms "analysis" and "synthesis," giving examples where chalk and carbon dioxide are involved.

13. Enumerate, with examples, the most important types of chemical change encountered in domestic science.

14. What are acids and alkalies and how would you recognise them? Give examples of each.

15. Explain clearly what is meant by inorganic and organic as applied to chemical compounds.

16. What are salts and how may they be prepared? Describe carefully how you would make specimens of common salt and chalk.

17. Write down the formulæ for ammonium sulphate, zinc chloride, calcium borate, and magnesium sulphate.

CHAPTER X

Water : its composition and value as a detergent agent—Hard and soft waters, and the softening of the former—Nature of soap and its action in washing ; free alkali in soap—Two common laundry and household substances, viz., “ Chloride of Lime ” and “ Salts of Lemon ”—Frost and sunshine as bleaching agents—Paraffin as a cleanser for (*a*) removing stains, (*b*) washing clothes, (*c*) household purposes.

Water is, of course, the most important substance used in laundry work, and no article of underclothing can be cleaned without the aid of at least this liquid.

How may the composition of water be demonstrated ?

Expt. 108. A current of electricity is passed through the water (with a little sulphuric acid added) contained in an apparatus called a Voltameter ; bubbles of gas are liberated from two platinum plates (placed in the water) where the current enters and leaves. These gases are colourless, and collect in the vessels over the platinum plates in the proportion of two to one. The larger quantity of gas burns with a pale blue flame and is hydrogen ; the other rekindles a glowing chip and is oxygen. A convenient form of Voltameter is the one called after its designer, Hofmann, and is so arranged that as the water is displaced from the two limbs by the pressure of the gases, it ascends a third connecting tube and thus creates a “ head ” of liquid. On turning the tap on at the top of either limb the gas is forced out and so may be tested (see Fig. 54).

The amount of sulphuric acid which must be added to the water varies according to the power of the current

employed. If a very strong one is used, none need be added; if the town supply of electricity is employed, about 1 part of strong acid to 500 of water; if a series of three or four electric batteries, use about 10 of acid to 100 of water. **This operation is called Electrolysis.** Only a few drops of the water required for filling the voltameter are decomposed by the current; in fact, the volume of it, if converted into steam, would be the same as that of the hydrogen collected, and water is about $\frac{1}{1700}$ part by volume of the steam it is able to generate. So that the actual quantity split up is exceedingly small. A certain volume of water on being decomposed will give a volume of hydrogen equal to that of the steam which theoretically could be obtained from it (and of course half this volume of oxygen).

The above experiment demonstrates the composition of water by volume, analytically, *i.e.*, by splitting it up into its constituent elements.

How may the composition of water by weight be determined? This is best done by *synthesising* or building up water from its elements.

Expt. 109. A stream of pure dry hydrogen is passed

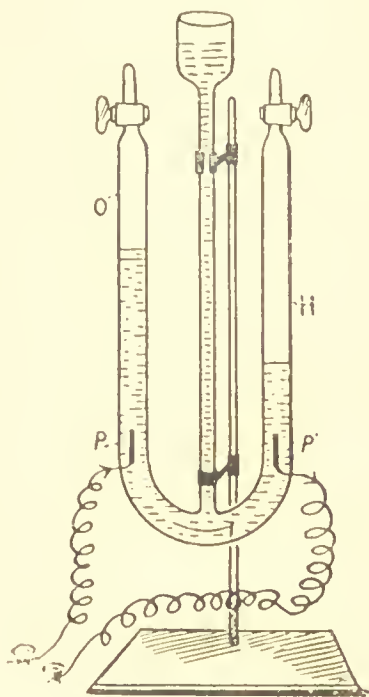


FIG. 54

Hofmann's Voltameter for the Analysis of Water.

- P. Platinum plates connected to electrical supply.
- O. Oxygen.
- H. Hydrogen.

The arrow shows the direction of the current.

over heated copper oxide, and the resulting gas collected in a U tube filled with a substance which absorbs water, *viz.*, dry calcium chloride. The copper oxide and calcium chloride tubes are weighed before and after the experiment. The former loses in weight (oxygen) and the latter gains (water). Water has been synthesised from the two elements, oxygen and hydrogen, so that if the loss in the copper oxide tube is subtracted from the gain in weight of the calcium chloride tube, the weight of hydrogen is obtained which has combined with oxygen to form the weight of water produced in the experiment. Thus the proportion by weight is determined (see Fig. 55).

Example of experiment :—

	grms. ¹
Weight of the copper oxide tube used before the experiment	= 34.54
Weight of the copper oxide tube used after the experiment	= 33.74
∴ the loss in weight = oxygen	= .8
Weight of the calcium chloride tube used before the experiment	= 23.62
Weight of the calcium chloride tube used after the experiment	= 24.52
∴ the increase = water	= .9

And the weight of hydrogen in this = $.9 - .8 = .1$ gm.; *i.e.*, .1 gm. of hydrogen has combined with .8 gm. of oxygen to form .9 gm. of water, or 1 with 8 to form 9.

The exact condition of the constituent gases in water has already been fully considered. They are combined and not mixed. **Pure water** is really quite bluish in colour, although it is usually said to be colourless; also odourless and tasteless. It boils ordinarily at a temperature of 212° F. or 100° C.;

¹ "Grm." is an abbreviation of gramme. There are 28.34 grammes in 1 oz. These weights were obtained by weighing on a *chemical balance* and not the ordinary spring variety (see Fig. 56).

freezes at 32° F. or 0° C. ; and, on evaporation to dryness, leaves nothing. It also does not change the colouring matters, or indicators, litmus and methyl orange. No other liquid possesses all of these properties or fulfils the whole of the conditions.

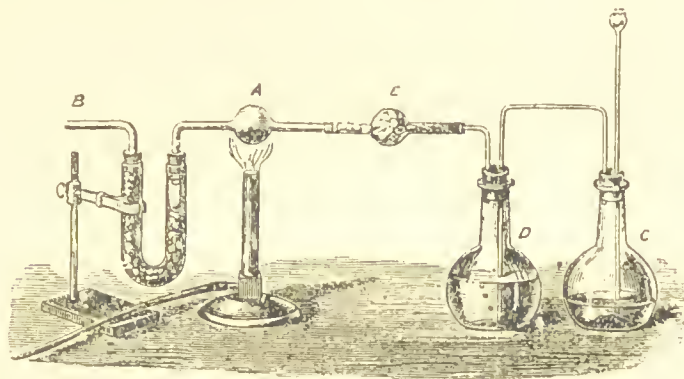
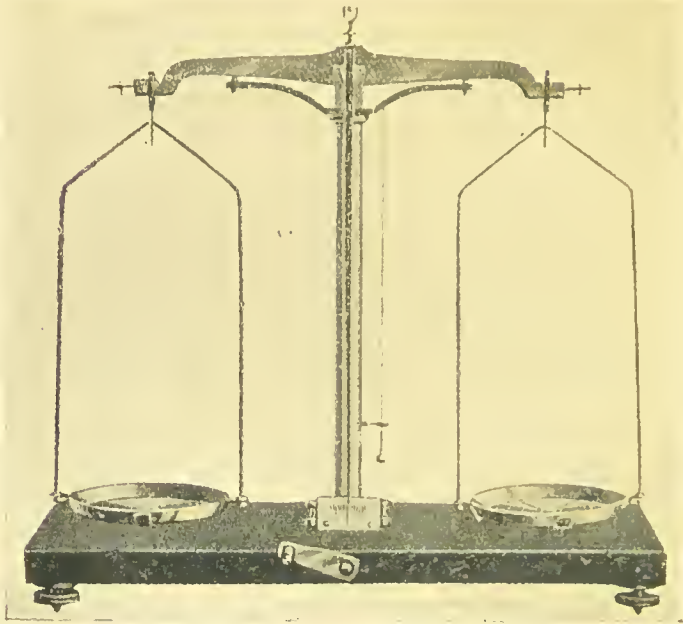


FIG. 55.—Apparatus for the Determination of the Composition of Water by Weight.

- A. Bulb containing Copper Oxide.
- B. Calcium Chloride Tube.
- C. Flask where Hydrogen is generated.
- D. Wash-bottle containing concentrated Sulphuric Acid.
- E. Tube containing Calcium Chloride.

Detergent Power of Water.—

Expt. 110. Take a piece of white blotting or filter paper and rub some fine dust or dirt on it. Shake it. Some little dirt will cling to the paper and soil it. No amount of mere shaking or knocking of the paper in the air will cause all the dirt to be removed. Now take a piece of white calico and repeat the rubbing-in of the dirt. Some clings to the article and no shaking or rubbing in air again removes all of it. But on placing the cloth in clean water and moving it about to and fro, nearly all the dirt is loosened and passes into the water. The more vigorous the movement in the water the more easily is



Balance.



Box of Weights.

FIG. 56.

the dirt loosened and removed from the fabric. This loosening and liberating power of water over dirt in an article of clothing is called **Detergent Power**, and is an exceedingly valuable one in laundry operations.

Expt. 111. Place a little salt in water. Very soon it has apparently disappeared. Put a little sugar in water. That also apparently disappears. Add a little powdered chalk, or powdered sealing wax, to water. They do not disappear but float about, making the water turbid, and perhaps eventually settle to the bottom. If a great many substances are tested in this manner it will be found that some behave like the salt and sugar, whilst others act like the chalk and sealing wax. When a solid placed in water seems to disappear it is said to be

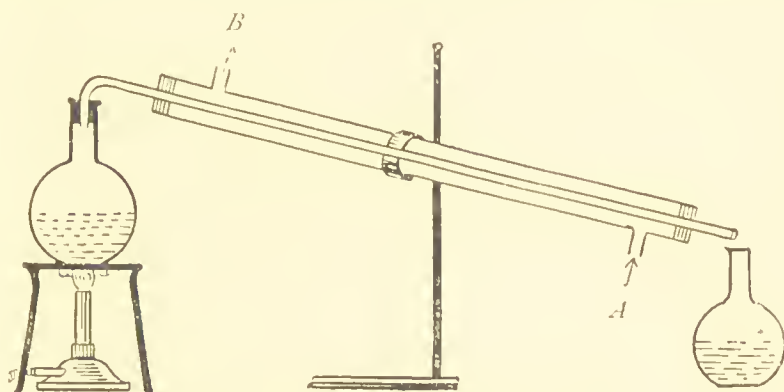


FIG. 57.—Apparatus for distillation of water.

A. Joined to water tap.

B. Communicating with a sink.

Soluble, and, on the other hand, when it does not disappear at all it is said to be **Insoluble**. Water is the *solvent* of these former substances, but since it does not dissolve all substances it is not a *universal* solvent. This solvent power is useful, but sometimes on the contrary, a nuisance in laundry work.

Hard and Soft Waters.—

Expt. 112. Distil some tap water from a distillation flask joined to a Liebig's condenser (see Fig. 57).

Expt. 113. Take 1 oz. of Castile soap, shred it, and add to a mixture of 1 pint of methylated spirit and $1\frac{1}{2}$ pints of

water ; wait until it has thoroughly dissolved. If this soap solution is always used in comparison experiments it is a *standard* solution, *i.e.*, one of known strength.

Expt. 114. Add a little of the standard soap solution from a burette to some of the distilled water, say 2 fluid ozs., in a bottle provided with a ground-glass stopper, and shake up. A lather is obtained immediately, which persists for at least five minutes without the bubbles breaking. Such a lather is called a *permanent* one. Now take the same amount of tap water and slowly add the soap solution until, on shaking, the same *permanent* lather is obtained. The amount of standard soap solution required will vary according to the nature of the water of the district, but in any case will be certain to be more than that required by distilled water. Suppose the amounts of soap solution are 1, 3, 6, and 9 measures or cubic centimetres (c.c.—the burette is graduated in c.c.'s) for distilled water, and three samples of different tap waters, or waters from different sources respectively. These last three numbers, less one, express the relative degrees of hardness of the waters. A water which does not almost immediately give a permanent lather on shaking with a little soap is said to be **Hard** ; one which easily forms a lather is said to be **Soft**. The greater the difficulty experienced in obtaining a permanent lather and the greater the amount of soap required, the harder the water.

What causes hardness in water ?

Expt. 115. Evaporate some freshly prepared distilled water to dryness in a porcelain dish—two or three lots in the same dish. Nothing is left. Repeat the experiment with the same amount of some hard water ; there is a residue in this case.

The hardness of water in general, then, must be due to some solid substance dissolved in it, for distilled water contains nothing, and is quite soft.

Temporary Hardness in Water.—It is often stated that the presence of calcium carbonate, chalk, or limestone in water renders it temporarily hard.

Expt. 116. Take some distilled water which has been previously boiled and cooled, but not exposed to the air for a long time, and add a little powdered chalk. Stir well but do not heat up, as temporarily hard waters are formed in nature without heat. Give the water plenty of opportunity for dissolving the chalk, then after settling, filter some of it and examine the clear, filtered water, (a) with standard soap solution, (b) by evaporating to dryness in a porcelain dish. Practically no more soap solution is required than before, in (a), and no residue is noticed in the dish, in (b). Evidently if water does dissolve chalk in nature, it must be different water from the pure kind used in the experiment.

Expt. 117. Fill a flask with tap water right up to the top of the neck and provide it with a rubber stopper and glass delivery tube, also filled with water, as shown in Fig. 58, and heat.

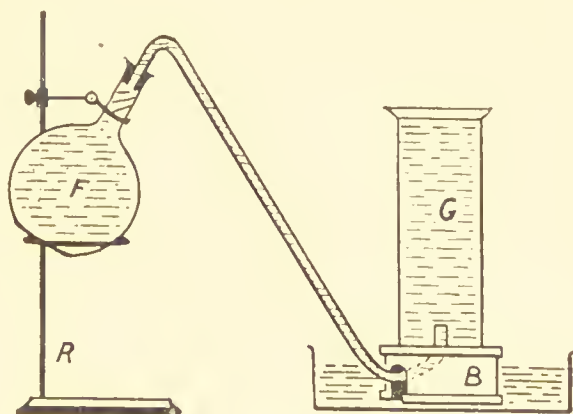


FIG. 58.

F. Flask full of Tap Water.
R. Retort stand.

G. Glass Jar full of Tap Water.
B. Bee-hive Shelf.

Some bubbles of gas collect in the inverted glass jar filled with water, and, tested with a lighted match, appear to be air, as the match is not extinguished.

Expt. 118. Expose some clear lime water to the air for about an hour. A white scum appears on the surface. Air has no smell, and the only odourless gas capable of reacting in this way with lime water is carbon dioxide.

Expt. 119. Fill a glass jar with carbon dioxide by pouring some hydrochloric acid on to some pieces of marble

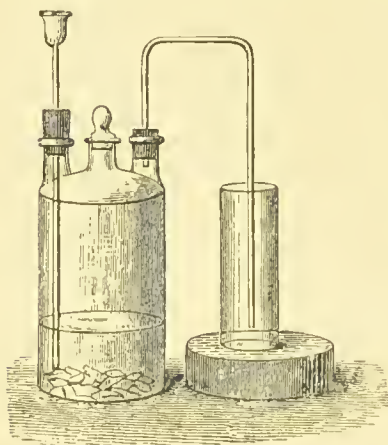


FIG. 59.—Preparation of Carbon Dioxide and filling a Jar with it.

covered with water in a Woulffe's bottle; collect the gas downwards (see Fig. 59).

When a lighted taper is extinguished at the top of the jar receiving the delivery tube, cover the top with a greased plate. Now place the jar, with the plate downwards, in some water in a dish so that the bottom edge of the jar is just covered by the water, and remove the plate. Keep it there for a few minutes with gentle shaking from side to side.

What happens? Water rises in the jar to the extent, perhaps, of one-third its volume, showing that this amount of gas has dissolved in the water and the latter has risen to take its place. Carbon dioxide then, dissolves in water, and is present in the air to a slight extent, but more particularly in soils; so that some will be present in the air expelled from rain, tap, well or spring water.

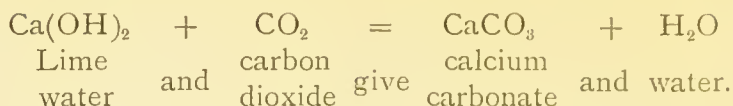
Is water containing carbon dioxide able to dissolve chalk?

Expt. 120. Take some distilled water which has immediately before been boiled and cooled, and sprinkle in a little powdered chalk, so as to make the liquid only slightly turbid. Generate some carbon dioxide by means of the apparatus used in the previous experiment, and bubble this through the chalky water very vigorously. It gradually becomes as clear as pure water. Now test some of this with the standard soap solution. It is difficult to obtain a permanent lather, a scum being preferably formed. The nature of this scum will be considered after dealing with the composition of soap.

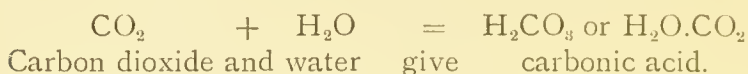
Water and carbon dioxide together, then, *are* able to dissolve chalk, rendering the water hard. Chalk, however, only exists free in the insoluble solid state; in temporarily hard water it is not visible, for it becomes changed by the carbon dioxide to *calcium bicarbonate*, so that **temporarily hard water is caused by the presence of calcium bicarbonate**. Similarly, hardness may be caused by *magnesium or barium bicarbonate*, as the carbonates of calcium, magnesium and barium occur in nature, the first two in great abundance.

Why is water, rendered hard in this way, said to be temporarily hard?

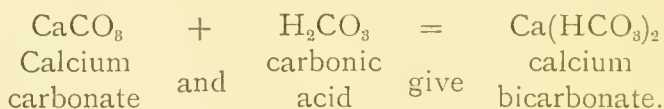
Expt. 121. Fill another gas jar with carbon dioxide, quickly add about one-fifth of this volume of clear lime water to it, cover with a greased glass plate, and shake. The lime water becomes milky, gradually reaches a maximum of milkiness, and then, on continued shaking, becomes clear again. The fluid left is calcium bicarbonate, and the water is temporarily hard. Some of the carbon dioxide in the jar unites with the lime in the lime water to form calcium carbonate and water, and the former, being insoluble in the latter, makes the whole milky. This reaction does not take place instantaneously, so the milkiness does not attain the maximum degree all at once.



Some carbon dioxide is left in the jar after this first operation, and this dissolves in the water forming a solution of it, or carbonic acid.



The dot between the H_2O and CO_2 implies in this case very loose affinity between them. The solution of carbon dioxide in water then slowly dissolves the calcium carbonate, and the whole becomes clear.



This calcium bicarbonate is a very loosely built up compound of the three constituents, calcium carbonate, water, and carbon dioxide; in fact, it may be represented as follows, the dots again implying very feeble combination:—



What will happen on boiling this temporarily hard water? The carbon dioxide will be driven off, leaving calcium carbonate and water; but calcium carbonate is insoluble in water, so it separates out, and *soft* water is left.

Methods of Softening Temporarily Hard Water.—

Expt. 122. (1) Boil some and allow the solid to settle. The clear water is soft, since the boiling expels the carbon dioxide and precipitates the calcium carbonate. The “furring” of kettles is caused in this way.

Expt. 123. (2) Carefully add lime water.

What is the action? The hard water contains free carbon dioxide, and this, combined with lime, forms

calcium carbonate, and the gas, as such, disappears. On adding lime water, then, the lime combines with the free carbon dioxide, forming insoluble calcium carbonate, and this action liberates the calcium carbonate which was already present. Thus, with careful addition of the requisite amount of lime water, soft water, and calcium carbonate are obtained. Allow to settle and pour off the soft water.

This method is worked on a commercial scale in **Clarke's Process**, or the **Porter** modification of it.

Suppose we also take a commercial or utilitarian view of the method. Let us assume that we are desirous of using thousands of gallons of water a day for a big laundry, and that the water happens to be very hard of a temporary kind. It will pay us to soften the water before use, by **Clarke's** process.

Expt. 124. Take 1 oz. of powdered dry slaked lime, add it to a quart of distilled or softened water in a stoppered bottle, shake for a few minutes, and then allow the residual lime to settle until the lime water is quite clear. This may take a few hours. Fill a burette with this clear lime water and run it into a $\frac{1}{4}$ pint of the hard water. A miliness, due to the precipitation of calcium carbonate, will be produced. When you think this miliness has reached a maximum, make a note of the amount of lime water run in and allow the precipitate in the vessel to settle. Now draw off a little of the clear supernatant liquor by means of a pipette (see Fig. 60), place it in a test-tube and add a little more of the lime water. Suppose a miliness is obtained. This indicates that not enough lime water had been added



FIG. 60.—Pipettes.

before. Start again with another $\frac{1}{4}$ pint of the hard water used and run in, say, 1 c.c. more of the prepared lime water from the burette than was added to the previous $\frac{1}{4}$ pint. Test the clear liquid in a test-tube as before. After repeated trials with the $\frac{1}{4}$ pint, addition of more lime water to the clear liquid above the sediment causes no milkiness. When this is reached one has added either (1) just enough lime water, or (2) a little too much, but certainly enough. An excess must be avoided, as it would make the water hard again. How can we test whether too much has been added?

Take a little of the clear water after settling and add a few drops of silver nitrate solution (made by dissolving silver nitrate or lunar caustic in distilled water). If a pale-brown or buff-coloured precipitate is obtained, too much lime water has been added; if no precipitate, exactly the right amount. In the first event, start again and add a little less lime water to the hard water until the exact amount required is obtained. The quantity required for a gallon or any number of gallons may then be calculated by multiplication.

Example of the experiment:—

A quarter of a pint of hard water (of a temporary kind) was taken and lime water added to it from a burette (the lime water being made by adding 1 oz. of dry slaked lime to 1 quart of soft water, shaking, and using the clear liquor). When 20 c.c. had been added, the milkiness seemed to have reached a maximum. This was allowed to stand until the precipitate settled. Some of the clear supernatant water was then sucked up by means of a pipette, put in a test-tube, and a little more lime water added. A slight milkiness was obtained. Evidently sufficient lime water had not been added before. Another start was made. A quarter of a pint of the hard water was taken and 21 c.c. of lime water added. After settling, etc., no milkiness was obtained on addition of more lime water. What did this show? Either

that (1) *just* enough, or (2) a *very* little amount too much had been run in. Silver nitrate solution was now added to a little more of the clear-treated water and a slight pale-buff precipitate was obtained. What did this show? That a little too much lime water had been added for the softening. Another start was made. A quarter of a pint of the water was taken and 20.5 c.c. of the lime water added, the precipitate allowed to settle, and the supernatant water tested with (1) more lime water, (2) silver nitrate solution. Nothing happened in either case. We had now obtained the exact proportions.

Calculations :—

$$570 \text{ c.c. (about) } = 1 \text{ pint.}$$

Therefore $\frac{1}{4}$ pint of the hard water required $\frac{20.5}{570}$ pints of lime water to be added.

1 pint of the hard water would require $\frac{20.5 \times 4}{570}$ pints of lime water to be added.

1 gallon of the hard water would require $\frac{20.5 \times 4 \times 8}{570}$ pints of lime water to be added (because there are 8 pints in a gallon).

And 1000 gallons of the hard water would require $\frac{20.5 \times 4 \times 8 \times 1000}{570}$ pints.

Or 1000 gallons of the hard water would require $\frac{20.5 \times 4 \times 8 \times 1000}{570 \times 8}$ gallons of lime water = 143.9 gallons of lime water.

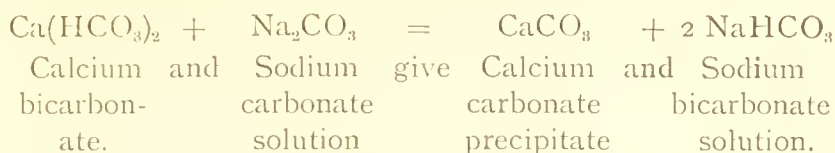
Of course the lime water should always be made up in exactly the same way by taking 1 oz. of the dry powdered slaked lime to 1 quart of soft water, or $\frac{1}{2}$ lb. to 1 gallon, or 50 lbs. to 100 gallons, and so on, and, after thoroughly stirring, allowing to stand, and using the clear liquor.

If the hardness varies from day to day or week to week, will this elaborate process of testing to determine the requisite amount of lime water have to be repeated each time? Not necessarily.

Expt. 125. Test $\frac{1}{10}$ pint of the hard water with the standard soap solution until the permanent lather is obtained after shaking. Suppose this requires 10 c.c. of soap solution. We then have the fact that when $\frac{1}{10}$ pint of the hard water requires 10 c.c. of standard soap solution, this same hard water requires 143.9 gallons of lime water to soften 1000 gallons of it. The next day or week $\frac{1}{10}$ pint of the hard water on testing requires, say, 9 c.c. of the same standard soap solution. Then 1,000 gallons of this hard water will require $\frac{9}{10} \times 143.9$ gallons of lime water to soften it = 129.51 gallons, and so on for other determinations (1 pint = 20 ozs.).

(3) **Allowing to stand or dropping any article in, tends to soften temporarily hard water.** Why? Because the dissolved carbon dioxide keeping the calcium carbonate in solution is slowly liberated, on standing, or more quickly from the surface of an introduced article. This liberation of carbon dioxide causes a deposition of calcium carbonate and so removes the hardening material. Excessive temporary hardness is often largely removed by agitating, or standing, or by both alternately.

(4) **Addition of a solution of Sodium Carbonate.** How does this soften the temporarily hard water? The hard water contains calcium bicarbonate, more or less. Addition of sodium carbonate solution causes a double decomposition, or exchange of partners, to take place, and one of the substances (calcium carbonate) being insoluble is precipitated. The other remains dissolved and does not cause hardness.



A little excess of sodium carbonate added does not matter as this in itself makes water feel soft.

N.B.—*Chalk, calcium carbonate, marble, and limestone are essentially the same in composition; they may differ physically, but not chemically.*

Permanent Hardness in Water.—The word *permanent* is here used in a *relative* sense. **A permanently hard water is one which cannot be softened by boiling**, in contradistinction from temporarily hard water. If a water is hard and a part of this hardness is removed by boiling and a part remains, the hardness is of the *two* kinds, viz., temporary and permanent. It is obvious that the substance causing the latter kind of hardness must be of different constitution and character from that giving rise to the temporary hardness, since boiling does not precipitate it.

Expt. 126. Take some distilled water and add a little crystal of calcium chloride to it; it dissolves. Test this with standard soap solution; it is hard. Boil some more of the water containing calcium chloride, cool, and test again with soap solution. The water is still hard and equally so, at least, showing that no softening has taken place.

Expt. 127. Similarly we could add a little plaster of paris or calcium sulphate, or common salt, to water, proceed as with the calcium chloride, and obtain similar results. *The presence of a little calcium chloride, calcium sulphate, or common salt, renders water permanently hard.*

Removal of Permanent Hardness.—To remove permanent hardness, one must endeavour to remove the calcium

salt in an insoluble form by double decomposition and precipitation, and so that the other salt produced and remaining in solution does not confer hardness. *A solution of sodium carbonate is best for the purpose.* If this is added in slight excess it is all the better for laundry purposes; in fact, in the case of the first three substances mentioned as causing permanent hardness it is necessary to add excess, as common salt itself makes water hard, and the sodium carbonate has, so to speak, to overpower this by its soapy property.

CaCl_2	+	Na_2CO_3	=	CaCO_3	+	2NaCl .
Calcium	and	Sodium	give	Calcium	and	Common
chloride		carbonate		carbonate		salt
solution		solution		precipitate		solution.

CaSO_4	+	Na_2CO_3	=	CaCO_3	+	Na_2SO_4
Calcium	and	Sodium	give	Calcium	and	Sodium
sulphate		carbonate		carbonate		sulphate
solution		solution		precipitate		solution.

With common salt there is no chemical change on addition of the sodium carbonate solution.

Soap.—The nature of this necessary household and laundry commodity is often not quite rightly understood by domestic science students. The preparation of salts has already been considered, when it was shown that a good method is to take the requisite base or alkali and acid, and allow them to mutually react upon each other. This formation of salts must be clearly grasped before the nature and manufacture of soaps can be understood.

Fats are the chief material in making soap. On being treated with what is called *superheated* steam, *i.e.*, steam at a higher temperature than 212°F . or 100°C ., they are split up into **glycerine** and **fatty acids**, but some steam is incorporated with the resulting products.

To say that a fat is a compound of glycerine (or glycerol) and a certain fatty acid is not correct in the same

sense that one shilling is equal in value to twelve-twelfths or ten-tenths, etc. of it. Why? Because the weights of glycerine and fatty acid produced by superheated steam are together greater than the fat decomposed, *to the exact extent of the water incorporated*. **Fats are, in fact, salts where the organic base is glycerine and the acid a particular fatty acid.** But since bases and acids react to form salts and water, the weight of the salt produced is not quite equal to the sum of the weights of the base and acid. *E.g.*, 40 parts of dry caustic soda react with 36.5 parts of dry hydrochloric acid gas to form 58.5 parts of common salt and 18 parts of water; *vice versa*, 890 parts by weight of pure beef suet on being treated with superheated steam chemically incorporate 54 parts of it and yield 92 of glycerine and 852 parts of a solid fatty acid which together equal 944 parts, whereas that of the beef suet is only 890. **Consequently it is better to say that fats are compounds or salts (called glycerides) which may be made to yield glycerine and a particular fatty acid (according to the fat decomposed).** The fat contains, as it were, the *nucleus* of *both* glycerine and the fatty acid, but *neither* as such, the application of superheated steam being necessary before the two are yielded.

Suppose we confine our attention to three substances of a fatty nature, viz., mutton or beef fat, olive oil, and palm oil. The chemical names of these in the pure state are respectively, **stearin, olein, and palmitin**, and the products obtained by the action of superheated steam, stearic, oleic, and palmitic acids respectively, and glycerine also in each case.

Soaps are sodium or potassium salts of these fatty acids and of a few other fatty acids of a similar nature.

Caustic soda and stearic acid yield sodium stearate (a soap) and water.

Caustic soda and oleic acid yield sodium oleate (a soap) and water.

Caustic soda and palmitic acid yield sodium palmitate (a soap) and water.

Caustic potash acts similarly but yields *soft* soaps, whereas caustic soda yields *hard* soaps. This method of forming soap by the reaction of alkali and fatty acids, is given to make their nature quite clear and not because it is used on the manufacturing scale.

Manufacture of Soaps.—**Hard Soaps** are manufactured by heating up requisite proportions of fats, or fatty oils, with caustic soda, until the whole is homogeneous. The soap separates out and forms a solid mass on cooling, and the glycerine remains in the liquid portion. In some cases the soap is precipitated with salt. The glycerine is distilled off from the liquid part. The soap curd is separated, re-melted with addition of a very small quantity of caustic soda, and poured into moulds. If *mutton fat* is saponified in this manner the soap is a *stearate*; if *palm oil*, a *palmitate*; if *olive oil*, an *oleate*. Thus sodium stearate, palmitate and oleate are all hard soaps, and potassium stearate, palmitate, and oleate, soft soaps.

Experiments which may be performed with ordinary hard soap :—

Expt. 128. Does hard soap contain water? Take some soap, weigh it, shred into a weighed saucer or porcelain basin and place on a pan of boiling water to dry it (if that is necessary). Continue to heat for a few hours and weigh, after cooling and drying the under surface. It will be found to have lost in weight. Now continue the drying until it ceases to alter in weight. What is the percentage loss?

Example of experiment :—

Weight of the saucer used for the	ozs.
experiment	= 4
Weight of the saucer used for the	
experiment + shredded soap ...	= 8
∴ the weight of soap taken	= 4

	OZS.
Weight of the saucer + dried soap ...	= $6\frac{3}{4}$
∴ the weight of dried soap ...	= $2\frac{3}{4}$
And the percentage of dried soap = $\frac{2\frac{3}{4}}{4} \times 100$	= 69
And the percentage of water = $100 - 69$	= 31.

Free Alkali in Soap.—Some text-books state that soap contains about 8 to 9% of caustic soda, 61 to 62% of fatty acid, and 30% of water. If this amount of caustic soda were all in the free or uncombined state, soap would not be fit to use; it would take the skin off one's hands. What is meant by the statement then? Suppose we deal with sodium oleate. The proportions of caustic soda and oleic acid required to produce this soap are 1 and 7 respectively, yielding 7.55 of soap (dry) and .45 of water. This proportion of 1 and 7 means that $\frac{1}{8}$ th is caustic soda, or 12.5%. But this makes soap with .45 of water in 8 of soap, or a product containing only 5.6% of water. Since the ordinary soap contains about 30% of water it follows that less than 12.5% of caustic soda will be required, and this works out at about 8 to 9%, leaving the fatty acid at about 60%. But to say that soap contains 9% of caustic soda and 61% of fatty acid (the rest being water) is quite as erroneous as saying that common salt contains a certain percentage of caustic soda and a definite percentage of hydrochloric acid. These proportions are required to produce the soap and the salt respectively, but not only is water eliminated by the reaction, but the acid and alkali, as such, are completely changed. Take the case of salt. Both caustic soda and hydrochloric acid are poisonous in ordinary doses; yet they produce common salt on reacting with each other, *i.e.*, absolute disappearance of the individual properties.

Is there, however, *any free alkali* in soap? *i.e.*, any present as *caustic soda*?

Expt. 129. Take a piece of soap, shred it, place in a test-tube, and then add some methylated spirit. Warm gently by placing the tube and contents in hot water until as much as possible of the soap has dissolved. Now add a few drops of a solution of an indicator called *phenol phthalein* which gives a *pink* colour with free alkali, but *nothing* with acid or when alkali is absent. If a pink colour is obtained free alkali is present. But if a few drops of weak acid are added to overcome or neutralise the alkali it will usually be found that these are sufficient to completely discharge the pink colour, showing that only a little free alkali is present.

Expt. 130. *The amounts of free alkali in different soaps may be compared* by dissolving up equal weights in methylated spirit and then seeing how many drops of the same weak acid are required to neutralise the alkali. If one requires, say, three drops and another six, the second contains twice as much free alkali as the first.

Sodium Carbonate in Soap.—Sometimes this substance is added, especially in making dry soaps. It may easily be detected by its effervescing with an acid.

Expt. 131. Add a little acid to some soap and see if any effervescence occurs.

Sodium Silicate, Resin Soap, and Insoluble Material.—Sometimes sodium silicate is added to increase the weight. It acts as a partial cleanser, however. The resin in resin soap (made by addition of resin to the fat used) is of no use; it merely adds to the weight. Sometimes small pieces of grit are detected, indicating the presence of insoluble ingredients.

Action of Soap in Washing.—We have already considered the detergent power of pure water. Many articles are covered with a film of *grease* even when there is no visible suspicion of it. Examine a piece of filter paper; it looks perfectly free from grease. Yet in

estimating the amount of fat in milk by a certain method, ordinary filter paper is not used, but specially treated fat-free paper, because of the possibility of there being a little fat in the ordinary kind. Cold water will not dissolve grease.

Expt. 132. Melt a little grease, and then smear a very small quantity of it on to a cloth. Now rub some dirt in. The dirt sticks and is not released or removed on dipping into cold water. Try dipping into hot water. A little is now removed because some of the grease is melted and some of the dirt comes with it; most of it still remains. *What can there be in soap solution to clean the dirty cloth?*

Expt. 133. Dissolve some soap in methylated spirit and add phenol phthalein. A faint pink colour is obtained which is completely discharged on addition of one or two drops of weak acid. Add some water. The pink colour returns. Again discharge the colour with acid; again add water. The pink colour probably comes back again. What does this show? *That a little free alkali is liberated on using soap in water. This liberated alkali, obtained by partial decomposition of the soap, saponifies the film of grease associated with the dirty article. The dirt is liberated and carried away partly by the detergent and mechanical agency of the water and partly on the liberated fatty acid. In other words, the free alkali forms a new soap with the fatty acid of the grease, releasing the attached dirt.*

The action of soap in washing may, however, still be a matter requiring a good deal of patient investigation.

Action of Hard Waters on Soap.—Most hard waters contain calcium or magnesium compounds dissolved in them. *On using soap, no lather is obtained until the soap has reacted, by double decomposition and precipitation, on the calcium or magnesium compound.*

E.g., Sodium oleate solution + Calcium sulphate solution = Sodium sulphate solution + Calcium oleate precipitate.

The calcium oleate is a white curdy insoluble substance, and constitutes the scum noticed on commencing to use soap with hard water. When *all* the calcium has been precipitated the soap can begin to operate for cleansing purposes, but *not* before. This causes great waste of soap. In the London district alone, soap to the value of many thousands of pounds is wasted annually owing to the water being hard.

Two Common Laundry and Household Substances.

—(1) "**Chloride of Lime.**"—The best common term for this is Bleaching Powder. Mixed with water, and the residue allowed to settle, the clear liquid may be used for removing persistent stains on clothing. The addition of vinegar or other weak acid hastens the action, but may perhaps be too powerful for some articles. The active agent is chlorine, which operates in presence of water, liberating oxygen in a peculiarly active state, and this changes the stain to a colourless, or almost colourless, substance—*i.e.*, it bleaches it.

(2) "**Salts of Lemon.**"—This is used, as a rule, for removing ink stains or cleaning old straw.

Expt. 134. Add a few drops of ink to some water—sufficient to impart a colour to it, and then some "salts of lemon." In most cases the colour very soon goes, especially if black ink is used. The "salts of lemon" does not bleach, but by interaction between it and the ink, the resulting products are almost colourless. Friction and heat aid the removal of the ink stain. "Salts of lemon," however, is not a bleaching agent in the chemical sense.

Frost and Sunshine as Bleaching Agents.—It is well known that frost and sunshine, particularly the latter, are very valuable aids in making white clothes a good colour. This is because the *sunshine evaporation* of water on the article of clothing, and also the low temperature during

frost, generate a little *hydrogen peroxide*, and this is a mild bleacher. Hydrogen peroxide has some of its constituent oxygen in loose affinity, or, "nascent" as it is called; this easily unites with, *i.e.*, "oxidises" other substances and thus causes the bleaching. *Hydrogen peroxide* is used for cleaning and renovating old oil paintings.

Paraffin Oil as a Cleansing Agent.—This liquid is used for removing paint stains, washing very dirty cloths, and for general cleaning purposes. It is easy to explain its use in the first and last cases, as it is an excellent solvent for grease, and is used for making *thick* paint *thinner*. Consequently with a paint stain it *thins out* the paint, and friction does the rest.

For general cleaning purposes a little of it on a cloth will dissolve any grease associated with dirt, and the rubbing will cause the loosened dirt to come away on to the cloth.

In washing very dirty clothes or dusters a little of the oil is mixed with the water, and soap is used in addition. If the oil is not added, soaking the clothes in hot water seems to drive the dirt in. The paraffin oil assists in softening and loosening the dirt, and thus helps in the cleaning.

QUESTIONS.

1. Describe carefully the experiments you would perform to ascertain the composition of water by volume and by weight.

2. Five volumes of hydrogen are mixed with 3 volumes of oxygen and the mixture caused to combine by ignition with an electric spark. What will be the volume of gas remaining and of what will it consist if measured (*a*) at 100° C.; (*b*) at ordinary temperatures.

3. What weights of hydrogen and oxygen are contained in 5 lbs. of pure water and what is their condition in the water?

4. What is meant by the "detergent power" of water? Describe simple experiments which illustrate this important property.

5. When is a water said to be hard and when soft? How many kinds of hardness are there, name them and state how they are caused?

6. Two samples of water, both hard, but not equally so, are given you for investigation. Ascertain carefully (*a*) which is the harder of the two ; (*b*) their relative degrees of hardness ?

7. Two fluid ozs. of a temporarily hard water on being boiled give .32 grm. of chalk ; $2\frac{1}{2}$ fluid ozs. of another sample of hard water give .29 grm. of chalk on similar treatment. Which is the harder of the two and what are their relative degrees of hardness ?

8. What are the particular disadvantages of hard water for domestic purposes. If the supply of water for a laundry is hard and of a temporary kind, how would you proceed to investigate the hardness, overcome it, and successfully deal with the softening of 10,000 gallons daily ?

9. What different methods are employed for the softening of temporarily and permanently hard waters ?

10. Explain clearly the nature of ordinary hard soap. Why is it incorrect to say that (*a*) a fat is a compound of glycerine and a certain fatty acid, and (*b*) soap is a compound of caustic soda with certain fatty acids ?

11. How are hard soaps manufactured ?

12. Discuss the presence and determination of (*a*) water ; (*b*) free alkali ; (*c*) impurities in soap. What is the action of soap in washing ?

13. Two samples of hard soap are provided. Determine the relative proportions of free alkali in them.

14. Criticise the following statement :—Hard soap consists of 30% water, 61% of fatty acid and 9% of caustic soda.

15. In what manner does the sun act as a bleacher ?

16. How would you use paraffin oil as a cleaning agent for (*a*) washing dirty cloths ; (*b*) general household dusting and cleaning ?

CHAPTER XI

The reality of the air ; reasons for ventilation, and the means of bringing this about—The circulation of hot and cold water as exemplified in hot and cold water of the household—Heating with hot water.

IT is not necessary to demonstrate the reality of a solid, such as a brick, and a liquid like water ; they are both easily perceived. With air, however, there is no actual visible evidence of its reality. On the other hand, there is an abundance of everyday experience relative to the atmosphere, which even a schoolchild is familiar with and will readily furnish on being questioned.

Wind is air in motion, and this can be felt. It is the motive force driving windmills and sailing ships. Dust, pieces of paper, and small articles are blown about on a windy day, and, in extreme cases, trees are uprooted. Again, we breathe air regularly so many times a minute. When this ceases for only a little time (a matter of minutes) death ensues. It is inconceivable that we should be continually taking nothing into our lungs, breathing nothing out again, and that when we cease to breathe nothing, life itself ceases. We blow the fire with air from a pair of bellows ; aeroplanes, weighing perhaps half a ton, are able to glide through the air ; bicycle tyres are blown up with air. It is therefore only possible to conclude after this mass of common evidence that the air, although invisible, is some real thing.

If the air is something, it must occupy space, because everything, no matter how small, fulfils this condition. A speck of dust is perhaps hardly visible to the naked eye, but

it nevertheless occupies space, as a microscope will show. The air is everywhere—in a tumbler, a cup, a basin, etc. How much air is there in a tumbler? If a half-pint tumbler, there is half-a-pint of air; when the vessel is filled with a liquid, half-a-pint is poured in and the same volume of air displaced. If the air is prevented from escaping out of a vessel, shall we be able to pour a liquid in? If a tumbler is full of milk we cannot pour water in without some milk, or milk and water, overflowing; or if the milk is by any means prevented from spilling, we should be unable to pour any water in.

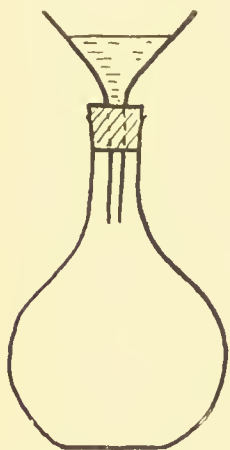


FIG. 61.—Apparatus for showing that Air occupies Space.

Expt. 135. Fit up the apparatus as shown in Fig. 61. A flask is provided with a good-fitting rubber stopper, through the one hole of which passes the stem of a funnel, so that the whole arrangement is gas-tight. Gently pour some water into the funnel. A few drops may pass down into the flask at the beginning, but practically the whole of the water stays in the funnel, just as if the end of the stem were sealed up. Why is this? Because the flask is already full of air, and water *cannot*

enter unless air comes out. As this is impossible, the water stays in the funnel. If the flask contained nothing at all, *i.e.*, if it were an empty space, what could prevent the water from immediately dropping down into the flask? *This experiment demonstrates that air occupies space.* How much space? As much as the full capacity of the vessel. What method can be adopted for measuring the volume of air? If a tumbler is half full of water, there is obviously half a tumblerful of air left, the level of water indicating how much air is present, *i.e.*, the volume

of the whole vessel minus that of the water. But suppose some air could be taken away from the half-tumblerful, would the level of water *now* indicate how much air was left or how much had been taken away? No, the level of the water would remain the same. *Can water in any way measure the volume of air in a vessel?* Instead of pouring water into a tumbler to see how much air is present, invert the tumbler under water. If any air were now taken away, the water in the tumbler would rise to take its place, owing to the pressure of air over the water surrounding the glass; and so, by difference of level, at once tell us how much had been removed. *This inversion of a tumbler is another method of demonstrating that the air occupies space.*

Expt. 136. Take a tumbler and fix two pieces of gum paper, inside and outside, so that they are the same distance from the rim, say, half-an-inch. Make ink marks on the two papers and, while still wet, thrust downwards underneath water in a dish or bowl, so that the level of water outside the tumbler is nearly high enough to cover it (see Fig. 62). Now remove the tumbler carefully by lifting vertically, and see what has happened to the ink. It will be smudged on the paper placed outside, but quite dry and clear on the corresponding paper inside. This shows that the water did not reach the paper inside. Why? *It could not, because the tumbler was filled with air.*

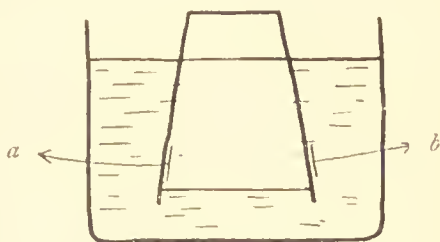


FIG. 62.—Apparatus for showing that Air occupies Space.

a. Gum Paper inside not smudged.

b. Gum Paper outside smudged.

It is rather inconvenient to abstract any air from the tumbler whilst in this inverted position over water.

Expt. 137. To see whether water will indicate change of volume by rising when air is removed, take what is called a bell-jar (see Fig. 63), provide it with a good one-hole rubber stopper and a short piece of glass tubing just passing through, and bent roughly at a right angle. Join a piece of rubber tube to the end of the glass, and fix on the former a screw clip. Proceed as follows: Remove the stopper, etc., from the bell-jar, and place the latter into some water in

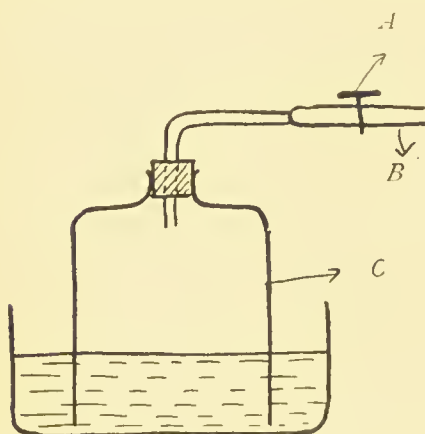


FIG. 63.—Apparatus to indicate change of Volume of Air.

A. Screw Clip. B. Rubber tubing.
C. Bell Jar.

a dish. Now replace the stopper and its fittings, open the screw clip, and suck some air out. Before removing the mouth, screw up the clip. What has happened? The water has risen in the bell-jar to take the place of the air drawn out. Open the clip again. The water falls to the old level, because air is drawn in through the tube. Blow down the tube gently and clip up tightly before stopping

the blowing. The level of the water in the jar is now depressed, indicating that more air is present than before. *Consequently difference of level of water can indicate alterations in volume or size of air.*

We have so far demonstrated that air occupies space, and indicated a means of measuring changes in volume by means of water.

Secondly, air must have weight.—In speaking of a speck of dust, or a feather, one is inclined to infer that it has no weight. This, of course, is so only in a relative sense. A bag of feathers is easily weighable, so that

one feather must weigh something. A cartload of dust may require hard work for one horse to pull. Logically, then, even one speck of dust must weigh something. By means of a very delicate balance it is possible to show that a piece of paper with a blacklead mark on it weighs more than without it. How would you demonstrate that anything, say tea, has weight? By taking some tea and placing a little on a spring balance; a certain weight is recorded. Add more tea. A greater weight is recorded, and so on. Or, *vice versâ*, weigh a bag full of tea and then show that the weight is less as the tea is taken out. Can either of these methods be applied to the weighing of air?

Expt. 138. Fit up a flask provided with a good rubber stopper, a short piece of glass tube passing through the one hole in it, a short piece of rubber tube attached to this, and with a screw clip attached. Have the clip open. Weigh on a good balance and leave the weights on the scale-pan. Now blow air in from the lungs as powerfully as possible, and, whilst blowing, screw up the clip. Weigh again. A slight increase in weight will perhaps be noticed. (N.B. It is best to use a spherical-bodied flask, and to support it by suspending from the hook of the scale-pan by means of a loop of wire fastened round the neck of the flask.)

Take the flask off the balance, and suck air out with an air pump, being careful to close the clip before suction stops, or drive some out by heating and screw up while hot. The flask now weighs less. The longer the air pump operates the greater the loss in weight. Evidently air has weight, for increase (air forced into the flask, as it is already normally filled) and decrease of it cause increment and loss in weight respectively. How can it be demonstrated that in the case of sucking, or pumping air out, that this abstraction did really happen?

Expt. 139. Invert the flask, place the glass and rubber tubes under water (the clip being still screwed up) and then open the clip. Water rushes up somewhat. This amount of water represents the volume of air which has been sucked or pumped out.

Thirdly, air exerts pressure.—No doubt most are familiar with the cheap scientific toy consisting of a circular piece of soft water-soaked leather, fastened in the centre to a piece of stout string. The leather pressed quite flat on a smooth surface becomes apparently glued to it, and a great amount of tugging is required before the leather is pulled away. This article is called a "*sucker*," and is the cheapest and best method of demonstrating the great pressure which the air exerts.

If the air exerts pressure, it must be exerted equally in every direction, inwards and outwards, etc., as we do not feel it pressing on our bodies. If one holds a thin sheet of paper in any upright position, the air must be pressing equally on each side, otherwise it would be torn or broken. If there was a wall of loosely stacked bricks, and one man trying to push it down on one side and another at the same time pushing equally on the other side, the wall would not be pushed over. If, however, only one man pushed, the wall would probably collapse.

Let us now return to the "*sucker*." The wet piece of leather pressed on a smooth surface of flagstone causes all the air between the two to be removed. Consequently there is air on *one* side of the "*sucker*" *only*, and the pressure it exerts on the leather is so great that it has almost the same effect as set glue. If, however, the "*sucker*" is raised from the flag, by turning up a little of it with the hand, air is introduced between it and the flag, and the whole is removed quite easily.

Expt. 140. Take a piece of glass tube, hold one end in the Bunsen flame, turning round slowly all the time until

it is quite closed up and the end red-hot and soft. Take out of the flame, quickly blow down it, slowly moving it round all the time. A bulb will be blown. Endeavour to obtain this so thin that it yields on gently touching with the finger. This very thin bulb remains quite intact so long as it is not interfered with, but almost as soon as it is joined to an air pump and air pumped out, it collapses. Why? The delicate balance between the inward and outward pressures of air has been disturbed, the internal pressure becomes less because of less air present, and the greater pressure of the air on the outside breaks the bulb.

Expt. 141. Take a tumbler, fill with water, press on a piece of ordinary white paper or thin card so that it is in contact with all the rim, keep the hand on it, and then gently turn the glass upside down. On taking the hand away the paper remains in position, because it offers a surface for the pressure of the air underneath, and this is much greater than the weight of the water. The water therefore remains held up apparently by the paper.

Many other experiments could be devised to demonstrate air pressure, all depending upon the disturbance of the equilibrium of the air. *Can the pressure of the air be conveniently measured?* Before experimenting it must be noted that if air is pressing on water or any other liquid, the pressure is transmitted through it with undiminished intensity.

Expt. 142. Take a narrow glass tube (say $\frac{1}{4}$ in. wide) closed at one end, fill it with water, put the finger on, and invert under some water in a vessel. Take away the finger and see what happens. All the water stays in the tube, because the pressure of the air on the water in the dish is transmitted through it and is able to support that column of water. Take now a larger tube and repeat. A similar result occurs. If a tube about 34 feet in length is used it will be found that the water in this tube sinks a little

from the top of it until the level is about 33 feet above that in the vessel or dish into which it dips. The pressure of the air on the surface of the water in the dish is transmitted through it and is able to support a column of water about 33 feet high. This

Water Barometer, as the instrument is called, is ordinarily too awkward to deal with; a clean, non-wetting liquid, $13\frac{1}{2}$ times as heavy as water, viz., mercury or quicksilver, is therefore employed.

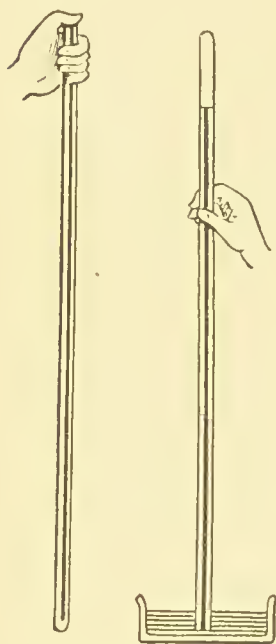


FIG. 64.—Mercurial Barometer.

Height from Mercury in Trough to that in Tube is about 30 inches. Space above the Mercury is a Vacuum.

Expt. 143. A tube about 34 ins. long is taken, of thick walled glass, closed at one end. It is filled with mercury, and then inverted under some mercury contained in a trough. The mercury sinks a little in the tube until its level is about 30 ins. above that in the trough. *This height of mercury represents the pressure of the atmosphere, i.e., air is able to support a column of mercury about 30 ins. high.* This height is not constant, but varies with the weather. The space above the mercury in the tube is quite empty, and is called a **Torricellian Vacuum**. A barometer which thus demonstrates the pressure of the

air, also measures it, and is a **Weather glass** (see Fig. 64).

We have so far been considering the physical properties of the atmosphere, *i.e.*, those properties which are *not* concerned with or characteristic of air *only*; for *all* gases occupy space, have certain weights or densities, and exert pressure.

We must now experiment to find out whether burning and breathing have any effect on the air, since these two actions are always taking place. The connection, if any, between burning and air is one which engaged the ancient philosophers for a great length of time, and for more than a hundred years they floundered hopelessly. Let us see if we can arrive at the correct explanation. If we are to establish general principles, it will not matter which burning article is taken for experiment. For convenience it will be best to choose a candle or a piece of phosphorus.

Expt. 144. Light a small piece of candle. Either (1) the candle burns by itself, or (2) it is dependent upon the air.

Expt. 145. Pour some clear lime water into a glass jar, cover with a greased glass plate, and shake for a few seconds. The lime water is not turned milky.

Expt. 146. Cover the burning candle with an inverted gas jar resting on the table or bench. The candle very soon goes out, and a slight mistiness (water) is noticed on the inside of the jar. Apart from this there is no evidence of change in the air, but it is obvious now, that the burning of the candle is dependent upon the air and a plentiful supply of it, since the candle soon goes out when deprived of fresh air by being covered up.

Expt. 147. Light the small piece of candle again and stick one end of a piece of iron wire into it so as to support it, and then lower into a gas jar containing a little clear lime water (see Fig. 65). After burning for a few moments take it out, cover the jar with a glass plate, and shake. The lime water is immediately turned milky, showing the production of carbon dioxide, as there is no pungent burning smell noticed.

So far, then, we have proved that the burning of a candle is dependent upon the air, and that water vapour and

carbon dioxide are produced. Evidently after burning has taken place, the air becomes altered in some way. In how

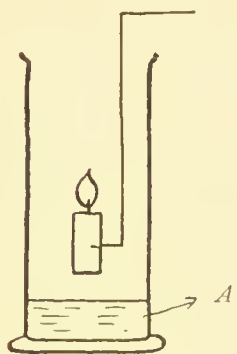


FIG. 65.—Apparatus for Burning a Candle over Lime Water.
A. Lime Water.

many possible ways can this occur? (1) By something being taken from the air, (2) by the air being completely removed, or (3) by something being added that will prevent further burning from taking place in it. So far, beyond the production of a little water and carbon dioxide, there is nothing to indicate exactly what takes place. If, however, the piece of candle is burnt in a bell-jar over water, the change of level of the water will tell whether the whole of the air has been removed, or some portion of it, or something been added.

Expt. 148. Take a small porcelain dish, float it on some water in a big dish (see Fig. 66), place on this small dish a piece of candle about an inch long, light it, and then cover with a bell-jar (with stopper off).

Replace the stopper as soon as the bell-jar is covering the candle in the porcelain dish. In a short time—varying with the size of the bell-jar—the candle goes out, and at the same time the water rises inside the jar to the height of about one inch. *Evidently when burning goes on in air some part of the latter is removed. Is it air? If so, the remaining gas will be air.*

Remove the stopper of the bell-jar and quickly put in a lighted taper. It is at once extinguished, showing

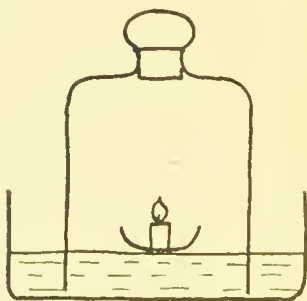


FIG. 66.—Apparatus for Burning a Candle in a Bell Jar over Water.

that the residual gas is *not* air. Therefore the burning candle removes a portion or constituent of the air while the burning takes place, and leaves another kind of gas which extinguishes a light. The next points to be settled are these:—(1) Has the candle in burning removed as much air as would a vigorously burning body? and (2) is the removal of gas on burning, peculiar to the candle and would it happen in the case of other substances? Suppose we perform a similar experiment with a small piece of phosphorus (kept under water until ready for use), which is a vigorously burning substance, and so settle these two points at once. The great advantage of experimenting with phosphorus is that the substance produced by its union with the gas necessary for burning, is very soluble in water and disappears as such; so that whatever gas is thus removed from air is in a few minutes completely evidenced by the rise of the water.

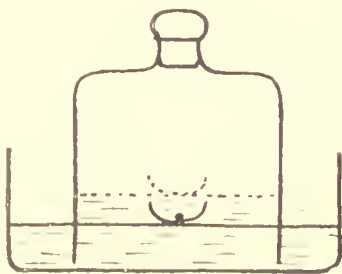


FIG. 67.—Burning Phosphorus in a Bell-Jar over Water.

Expt. 149. Take a small porcelain dish, place in a small piece of dry phosphorus, float it on the water in the big dish, cover with the bell-jar (stopper off), touch the phosphorus with a warm glass rod, and as quickly as possible replace the stopper and press down slightly. The phosphorus bursts into flame, giving off dense white fumes, and then slowly dies out (see Fig. 67).

On standing for ten minutes or a quarter of an hour the gas remaining in the bell-jar becomes quite clear, and it is noticed that the water has risen inside much higher than in the case of the candle. On testing the remaining gas with a lighted taper, the latter is extinguished. Therefore, comparing this result with that in the case of the burning candle, we see that not all the removable gas was then

taken away by it, as shown by the increased rise of the water after the phosphorus had burnt.

We now know that the burning of any substance is (1) dependent upon the air, but not upon the whole of it ; (2) that the air contains at least two different gases ; (a) one required by and combining with burning substances, and (b) one not required to aid and support burning. The gas required before burning can take place in air is called **Oxygen**, the other **Nitrogen** ; they are present in air *mixed* in the proportions by volume of 1 and 4 respectively. The substances produced by union with oxygen are called *oxides* ; the burning of any substance in air, *i.e.*, combustion, involves the process of *oxidation* and the production of oxides.

Whenever combustion is going on in the air, oxygen is being taken away, leaving a mixture of gases richer in nitrogen and poorer in oxygen, provided, of course, no fresh air replenishes it. **Nitrogen** is a gas which does not support life ; **oxygen** is the life giver. Consequently air impoverished by combustion is not so good to breathe. Almost all combustible substances contain the element carbon in combination. On burning, this carbon unites with the oxygen, producing carbon dioxide, and, in some cases of incomplete burning, carbonic oxide as well. Carbon dioxide is suffocating and slightly poisonous ; carbonic oxide is *very* poisonous. So that burning not only removes the vital constituent of the air necessary for the continuation of life, but leaves in its place gases which are suffocating and poisonous. *The necessity for fresh air to replace air depleted and contaminated by combustion, is therefore obvious.*

What effect has breathing on air ?

Expt. 150. Take some clear lime water and blow into it by means of a piece of glass tube. It very quickly becomes turbid. Carbon dioxide then is being sent into the air

whenever breath is exhaled from the lungs. There is a *little* carbon dioxide in the air before inhaling, but not nearly so much as that in the expired air. The following apparatus demonstrates this (see Fig. 68):—

Expt. 151. Two Woulffe's bottles are fitted up (as shown) with rubber stoppers and glass tubes. Both contain clear lime water, and the tubes *b* and *c* dip into this, *b* in one bottle and *c* in the other. On blowing down the T piece *a*, the bubbles of expelled air pass through *b* alone

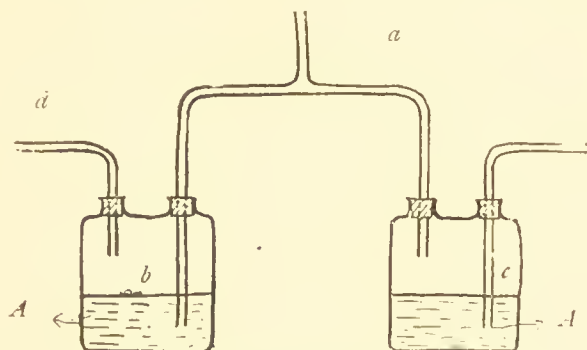


FIG. 68.—Apparatus for contrasting the amounts of Carbon Dioxide in Inspired and Expired Air.

A. Lime Water.

and out through *d*, soon turning the lime water milky. Count the bubbles or time the blowing with a watch. Now suck in at *a*. This causes ordinary air to pass through *c* alone and into the mouth. Allow the same number of bubbles to pass through as passed through *b*, or allow the same time to elapse. As a rule, no appreciable milki-ness is obtained in the latter case, even after a minute, showing that the amount of carbon dioxide in air is much less than that in the breath. How has the carbon dioxide in the expelled breath been produced? By the slow oxidation of the tissues of the body by some of the oxygen of the air inhaled. Breathing depletes the air of about 5%

of its oxygen at each inspiration and contaminates it with an equal amount of carbon dioxide. A room, closed up as much as possible, holding many people, and with the gas lit, is very unhealthy, because of the continuous depletion of oxygen, and contamination with carbon dioxide. Further, in a crowded room the organic impurities exhaled by people increase with the carbon dioxide and these make the air "stuffy." Micro-organisms of disease flourish and people are, on the whole, rendered more receptive to any disease-germ or bacillus which may be present in a vigorous condition in the foul air.

Gases lit, fires burning, many people breathing, all make the re-freshening and replenishing of the air in a room imperative.

Expt. 152. Hold a thermometer about six inches above a Bunsen flame and notice how the temperature rises. Then hold it six inches from the burner in a horizontal position, *i.e.*, to one side. The temperature does not rise so much as in the first case. Why? Hot air is *rising* and not passing sideways. In a warm room, it is always hottest near the ceiling. On opening a window at the top, cold air can easily be felt pouring downwards into the room. Cold air sinks. *The principle of natural ventilation, then, is to allow fresh and cooler air to enter—low down in the room preferably—and the warm and stale air to leave near the top.* A window opened top and bottom, and a fireplace with a ventilating grate near the ceiling, are sufficient outlets and inlets for natural ventilation to take place. The many elaborate mechanical devices to aid ventilation cannot be considered here as we are only dealing with fundamentals. The spontaneous movement of air owing to difference of temperature between several portions of it, when communication is suddenly made between them by opening a door or window, etc., is called **Convection**.

Circulation of Water.—Just as there are convection currents in air, so we have similar movements in water if, and so long as, difference of temperature exists, and provided there is no barrier to the movement.

Expt. 153. Place some water in a large flask, stir a little bran into it, and then heat on a tripod and wire gauze over a lamp. The pieces of bran, being light, follow the

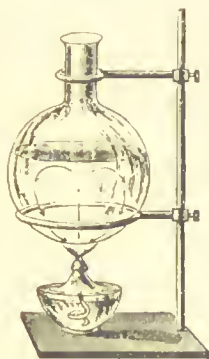


FIG. 69.—Experiment illustrating Convection.

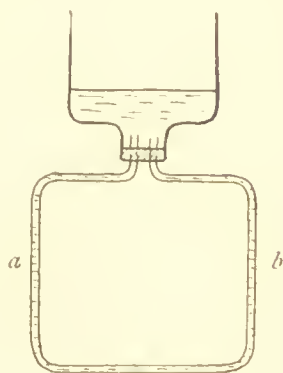


FIG. 70.—Apparatus for showing Circulation of Water.

motions of the water, and will be seen to rise up the centre and down at the sides (see Fig. 69).

An excellent apparatus for showing these movements is the following (see Fig. 70):—

Expt. 154. An inverted bell-jar is attached to the glass tubes *a* and *b* which are completely filled with water. The bell-jar also contains some water communicating with that in the tube arrangement. On warming the limb *a* at about the centre of it and simultaneously pouring ink into the jar, the colour starts going down *b* only and then passes round up *a* until the whole is blackened. Why does the ink at first only go down *b*? Because the water in *a* is becoming lighter on warming

and rises, inducing a cooler and downward current of water to traverse *b*; this is inky, and so the current is made evident. There is really no necessity for any experimental demonstration of the circulation of water; everyday experience is sufficient. In houses fitted with a hot and

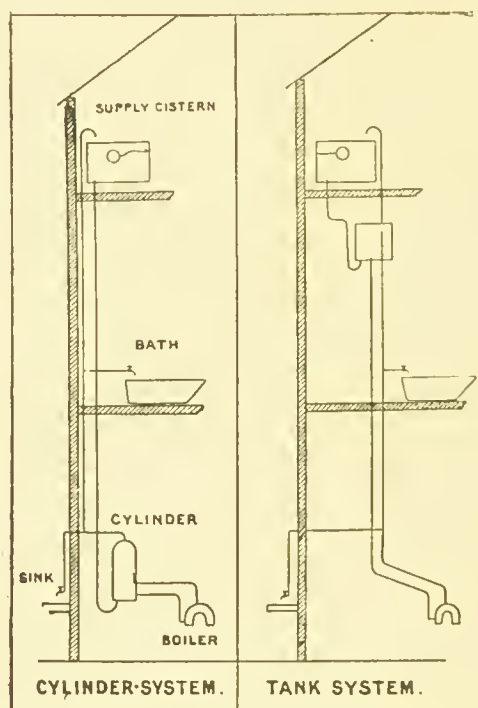


FIG. 71.— Cylinder and Tank Systems in Household
“Hot and Cold Water.”

cold water system, and where the fire heating the boiler has not been lit long, the water at the top of the cylinder (placed higher than the boiler as a rule) may be warm, but the water lower down quite cold. It is clear that the hot water must have risen spontaneously by convection currents. On the other hand, cold water sinks. In the hot and cold water system of a house (see Fig. 71) it

will always be found that the hot-water pipes come from the top of the boiler and cylinder, and the cold-water pipe from the cistern (placed higher up), conveying water to replace the hot water drawn off, enters at the bottom. The cylinder is usually made of copper, and should be kept bright, as in this condition it loses less heat to the air. Both the supply pipe and escape pipe for hot water may become frozen in severe weather. The supply of water is then stopped, and the boiler and cylinder may boil dry. This would not happen, however, without some indication by vigorous boiling. In the tank system (see Fig. 71), which is cheaper, the hot-water branch pipes are taken from the hot-water flow pipe and a big tank high up in the house supplies the cold. Care must be taken to see that the tank of water is always full and the downward flow pipe of cold water quite free.

The heating of buildings with hot-water pipes and radiators is entirely based on the convection currents of water and radiation. The radiators are invariably painted dull black, as this colour allows more heat to pass or radiate into the surrounding air. The above is a diagrammatic representation of the system (see Fig. 72).

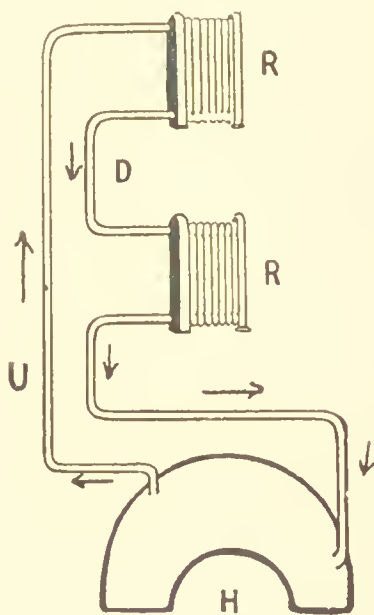


FIG. 72. Heating of Rooms by Convection and Radiation.

- H. Source of Heat ; Boiler just above.
- R. Radiators.
- U. Up pipe.
- D. Down pipes.

QUESTIONS.

1. What common evidence is there of the reality of the air?
2. Explain clearly how it is possible to measure alterations in volume of a gas by means of water.
3. Describe experiments designed to prove that air (*a*) occupies space; (*b*) exerts pressure; (*c*) has weight.
4. Describe the construction of an ordinary mercurial barometer. What are the advantages and disadvantages of one made with water?
5. Describe experiments, in their proper sequence, which fully establish the fact that air and burning are closely connected with each other.
6. How can it be shown experimentally that the air consists of at least two different gases?
7. Explain the necessity for ventilation in an ordinary living-room and the principles involved in bringing this about.
8. What are the essential differences between inspired and expired air? How would you demonstrate these differences?
9. Explain what is meant by "convection currents" in air and water respectively. How can they be easily evidenced, or their presence demonstrated?
10. Describe, with sketches, the system of heating a building by means of hot-water pipes and radiators.
11. What are the best conditions for the successful working of the following: (*a*) a household cylinder; (*b*) a kettle?

CHAPTER XII

SOME POPULAR EVERYDAY MISNOMERS AND DOMESTIC FALLACIES.

THE number of misnomers and fallacies in almost daily use is very large. For some inexplicable reason it has come to be regarded as necessary that a name for use amongst the ordinary non-scientific majority must be somewhat incorrect, or that popular names and popular science must be slightly removed from the exact truth to make them easier to remember or understand. The following are the most common misnomers that are met with in domestic science :—

“**Chloride of Lime.**”—Calcium carbonate is often called by the somewhat old name of *carbonate of lime* ; the latter cannot be called incorrect, but rather out of date. If carbonate of lime is calcium carbonate, *chloride of lime* must logically be calcium chloride. But it is not. Calcium chloride is a substance devoid of smell, existing in two forms, one quite dry, and the other crystalline. The former exposed to the air abstracts moisture from it and then yields a solution in water. The so-called “*chloride of lime*” has a peculiar odour like weak sickly chlorine and does not become wet on exposure to the air of a room. The dry calcium chloride is said to be deliquescent and “*chloride of lime*” is not. Addition of a weak acid, *i.e.*, hydrochloric acid to real calcium chloride causes no gas to be evolved, but in the case of “*chloride of lime*” the yellowish-green, pungent, bleaching chlorine is given off. Calcium chloride is prepared from slaked lime and hydrochloric acid ; “*chloride of lime*” from dry slaked lime

and chlorine. One can scarcely expect people to assign to "*chloride of lime*" its correct chemical term (calcium chlorohypochlorite and some unaltered slaked lime), but why not the term **Bleaching Powder**, which has the advantage of indicating the kind of substance it is. *Exact nomenclature in domestic, as in the other sciences, cannot be too strongly urged*, for as long as inexact terms are retained confusion and vagueness will result, and progress will be slow.

"**Liquid Ammonia.**"—It is very likely that few who read this book have ever seen *real* liquid ammonia. The mistake arises in the confusion of a *liquid* and a *solution*. **Ammonia** is a light gas (often called "volatile alkali") with an extremely pungent, peculiar odour, and in this gaseous condition is not at all suitable for use in the household. One would require a gasometer to hold it, and this would mean that very few would be able to avail themselves of a valuable cleansing agent. Fortunately, ammonia gas is exceedingly soluble in water—in fact, the most soluble gas known—and the solution has all the virtues of the gas. The "*liquid ammonia*" of the shops is a more or less pure, strong, solution of the gas in water. The chemical name for this is *Ammonium hydroxide* or *hydrate*. If a correct common term is desired, call the product *Ammonia solution*. What is *real* liquid ammonia? By the application of cooling and pressure, chemists have now succeeded in changing all gases into the liquid form. This is a very difficult task to accomplish in some cases, but fairly easy in others, *e.g.*, ammonia. If ammonia is cooled and compressed, it liquefies without water touching it. This is *liquid ammonia* which cannot be easily bought as can the other erroneously named liquid.

"**Salts of Lemon.**"—"Salts of lemon" is certainly a salt, but that is all one can say in favour of the expression. Why "salts"? Are there two or more? No: "*salts of*

lemon” is one salt. No lemons are used in the manufacture of the substance. On the contrary, “*salts of lemon*” is extremely poisonous. The juice of lemons is practically a weak solution of citric acid, and if crystals were obtained they would be *citric acid*. “*Salts of lemon*” is acid potassium oxalate or potassium binoxalate, a very different substance.

Expt. 155. Prepare some “salts of lemon” by taking potassium carbonate, dissolving in water, and then adding a solution of uniform strength of oxalic acid solution until, on testing a drop of the resulting solution, no change in colour with litmus is noticed. When this occurs add another lot of the same oxalic acid solution *equal* to what has already been added, evaporate to smaller bulk in a porcelain dish, and allow to cool. Crystals of the potassium binoxalate, *i.e.*, “salts of lemon,” separate.

Copperas.—This contains no copper. The chemical name for it is Ferrous Sulphate crystals; a correct term is protosulphate of iron, to distinguish it from persulphate of iron.

Oxidised Silver.—Metallic silver on being exposed to the air soon tarnishes, especially in town air, becoming almost black on the surface. This is due to the formation of a compound of silver and sulphur on the silver surface, by surface reaction between the metal and the volatile sulphur compounds in impure air. Consequently silver goods have to be constantly cleaned. If, however, they are tarnished to start with, impure air cannot have any further action, as the metal itself is protected. To obtain this so-called “oxidised” effect, the article is cleaned and placed in a solution of potassium or ammonium sulphide, and this soon coats it with a greyish-brown film of *silver sulphide*. *Real oxidised silver* would be the substance obtained by the union of silver and oxygen.

Oxidised Copper.—Similar remarks apply to this as to *oxidised silver*.

Galvanised Iron.—There is no galvanism or electricity employed in the preparation of galvanised iron. Iron very soon rusts in moist air and may become so badly corroded as to be quite porous. To prevent this action as much as possible, the sheet iron is dipped into molten zinc and thus becomes coated with the latter metal. Zinc, on exposure to air, forms at the most, white spots on its surface, but nothing that is really noticeable at a distance. Galvanised iron, then, has really no iron exposed at all; it is *zinc*, as the iron itself never reaches the air as long as the veneer of the metal is not knocked off. When this happens, the iron rusts quite as easily as ordinary iron.

Tin Goods.—Tin is also largely used for protecting iron from the air and so preventing it from rusting. Tin is a soft and comparatively dear metal. A fairly large so-called "*tin-can*" may be bought for a penny, but not a *real* tin-can of the same size. So-called tin goods are made by dipping sheet iron into a bath of molten tin, and then working up the tinned iron into the desired shape. As with galvanised iron, tin cans will slowly rust if water is left in them for long and exposed to the air, as the thin coat of tin is not then sufficient protection.

German Silver.—This is an alloy or mixture of the fused metals copper, nickel, and zinc in the proportions of 4, 2, and 1. It is made by melting up the three metals together and then solidifying. The name was given to the alloy because it was first made in Germany.

Mosaic Gold.—This contains no gold. It is tin persulphide prepared by heating powdered tin, sulphur, and sal ammoniac.

Although not exactly coming under the head of either

misnomer or fallacy, it is advisable to be quite clear about the different varieties of lime. **Quicklime** is calcium oxide (CaO). On addition of water it slakes, evolving great heat, and crumbles to a powder quite as dry in appearance as the quicklime. Fifty-six parts of quicklime unite with 18 of water, forming 74 parts of dry **Slaked lime** (Ca(OH)_2). If a little of this is added to water, it dissolves. The clear solution is called **Lime Water** (Ca(OH)_2). If more of the slaked lime is added, the material becomes milky and is called **Milk of Lime**. Addition of more of the slaked lime makes it quite pasty. This is the **Builder's Lime**. **Limestone** is calcium carbonate (CaCO_3). To sum up:—

Quicklime is CaO (dry).

Slaked lime is Ca(OH)_2 ; also visibly dry.

Lime water is Ca(OH)_2 ; water containing a little dissolved slaked lime.

Milk of lime is Ca(OH)_2 ; lime water containing some slaked lime in suspension.

Builder's lime is Ca(OH)_2 ; almost all slaked lime and only a little water to make it pasty.

Limestone is CaCO_3 .

Some Vague Expressions.—Many expressions are commonly used that are imperfectly understood owing to a lack of knowledge of the scientific principles involved, *e.g.*—

The barometer is "falling" or "going back."—In what sense is it *falling*? The *level* of mercury in the long barometer tube is being *lowered* or is *falling*. The following, and the diagrams of the front and back of an ordinary weather glass (see Fig. 73) will explain the "*going back*."

Instead of the form described previously in Chap. XI., most barometers have the bottom of the tube bent round to form a **U**, and this short tube takes the place of the trough containing mercury. A little weight rests

upon the mercury in the small tube and therefore moves up and down as the mercury rises and falls in the long tube. A cord attached to this weight or "float" passes over a pulley connected with a pointer which can turn like the hand of a clock. When, therefore,

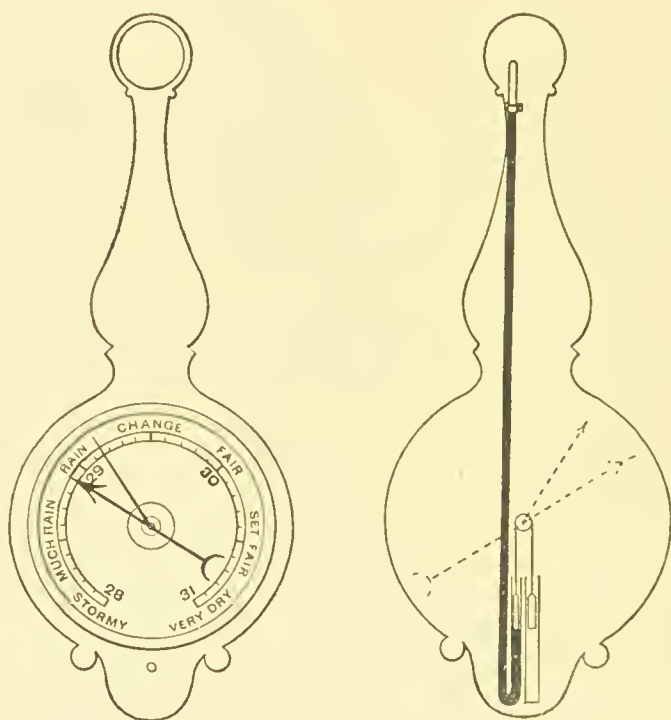


FIG. 73.— Front and Back of a Barometer or Weather Glass. The instrument indicates changes in the pressure of the Air, and consequently alterations in the weather.

the mercury moves in the tube the float rises or sinks and turns the finger or indicator. Marked upon the dial are numbers corresponding to the length in inches of the long mercury column measured from the level in the small open tube. The height of the barometer can then be read off by noticing where the pointer is at rest. The word "**Rain**," is

placed on the left of the dial, and "**Fair**," and "**Set Fair**" on the right, with "**Change**" at the top between the "**Rain**" and "**Fair**." If the pointer is at "**Fair**," and then moves to "**Change**" this is the "*going-back*" spoken of; the level of mercury is now *lower*. A short stationary pointer not connected with the mercury but adjusted by hand, is often added to indicate how much the mercury level has risen or fallen during any period. One often refers to the "*setting*" of the barometer, *i.e.*, making the short hand superimpose the indicator one. If set in the evening and the pressure of the air alters during the night, the exact amount of this alteration can be seen the following morning.

"**The air is heavy to-day!**"—When this exclamation is made, a glance at the barometer will show that the *level* of mercury is *not so high* as usual; in fact the air is *lighter*. If people say that they themselves feel heavy, the matter is easily explained. When the pressure exerted by the air is rather suddenly diminished, the internal blood pressure may not at once adjust itself to the altered external conditions, with the result that it is greater than that of the air. The blood moves to the head more than normally and causes a headache. We are feeling dull and heavy, but the pressure of the air is actually less than usual. On days when the mercury in the barometer is high, the weather is usually bright and clear and we ourselves feel correspondingly lighter.

Domestic Fallacies.—Let us start with a statement which hundreds assert is not at all fallacious. We shall deal with it at some length since it shows how necessary is some knowledge of science, if foolish superstitions are to be suppressed and action or observation made intelligent. This is the statement:—

(1) **That the sun shining on a fire puts it out.**—Many people unfamiliar with science, but observant of ordinary events, are convinced that the sun shining on a fire *does*

put it out. They have noticed it very often. Anyone with but a slight knowledge of the principles underlying heat phenomena will see how foolish this belief is. Here are the arguments :—

(a) *For putting out.*—The experience of housewives who insist in stating that they have had a fire extinguished by the sun, but cannot explain why. Science tells us, however, that the air near the fireplace may become more rarefied owing to the warmth, and tend to pass up the chimney without first passing through the fire. If this is so, less combustion would go on, causing the fire to burn less brightly.

(b) *Against putting out.*—Sunlight is extremely powerful, and it is almost impossible to see the flames from the fire in the full glare of the sun ; the fire's feeble light is overpowered. We are unable to see a Bunsen flame in sunlight. When the colour of the fire-flames is softened by the sun it is possible to see the brownish-grey ash left by the combustion of the coal, and this gives the appearance of a dying fire. Without the sunlight, it is impossible to see the ash, but quite easy to see the yellow coal-gas flames.

Expt. 156. Let us suppose the sun is shining on a fire. Lower the blinds ; the fire is burning with a warm glow. Now draw up the blinds ; the fire seems to be going out.

The fire can scarcely be going out one moment, burning brightly the next, and then going out again at the third. Moreover, if one is sitting in a room with a fire and the sun happens to be pouring in through the windows, incidentally directed on to the fire, the warming effect of the sun is generally greater than that of the fire ; the latter is not needed. So in the genial, radiant warmth of old Sol we are quite happy ; perhaps go to sleep, and the fire does likewise for want of attention. Or a fire is lit and then left. This neglect sometimes results in the fire

dying down and going out. Incidentally, the sun may have shone on the fire, and the two occurrences are linked.

(2) **That the sun raises the dust.**—The atmosphere is full of extremely small particles of dust. These are invisible in ordinary diffused light, but become apparent in sunshine. *But they are present all the time.* It is due to these particles that light is made evident. If a room is darkened and a streak of light allowed to enter through a slit in the blind or shutter, the light may be interrupted by holding a Bunsen burner in its path. At the place where the lighted flame is held all the dust particles are burnt up and there is a dark patch. It is clear, therefore, that sunlight does not raise dust, but that dust is necessary to produce a sunbeam.

(3) **That a dirty ceiling above a light is always due to soot.**—The same darkening is often observed above radiators where there is *no* flame and consequently *no* soot; also on the ceiling above any hot surface, apart from actual flame. This third fallacy is linked with the second. The air above a hot surface becomes heated and rises, causing a peculiar flickering often observed. A ceiling is porous, particularly in the spaces between the laths, and the dusty, and perhaps dirty air is filtered, the dust remaining in the plaster, and by its accumulation causing the darkening. In some cases of dirty ceilings it is quite easy to see how the laths are placed; the cleaner portions are invariably below the laths, and the darker streaks the spaces between them. Of course it sometimes happens that the blackening *is* due to soot.

(4) **That a light introduced into a gasometer would result in a violent explosion.**—A lighted match dropped into a gasometer, with the admission of no air, and the emission of no gas, would result in the match going out and the gas

not burning or exploding. The reason is easily made clear if it is borne in mind that no single substance can burn absolutely by itself or in itself. The coal-gas requires air before it can burn. The burning match requires air. Thus the match goes out and the gas does not burn or explode. Of course if air were mixed with coal-gas in correct proportions, and a light applied, there would be a violent explosion, as many amateur plumbers have discovered to their cost when looking for a gas leak with a light.

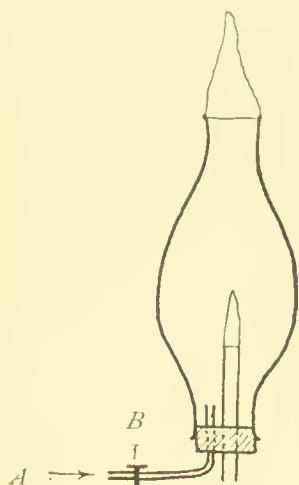


FIG. 74.—Apparatus for showing that Air burns in Coal-gas.

A. Stream of Coal-gas.

B. Screw Clip.

(5) **That air will not burn under any circumstances.**—That this is erroneous follows, if air and another substance are required before burning can take place. The substance which burns is called the “combustible body,” the other, reacting with it to cause a flame, the “supporter of combustion.” Since we must have two different reacting substances for a flame to be produced, they are quite *relative* with regard to each other and might take each other's place. If coal-gas burns in air, air ought to burn in coal-gas. The following simple apparatus

demonstrates this (see Fig. 74).

Expt. 157. A lamp chimney is provided with a two-holed rubber stopper. One hole admits a piece of narrow glass tube bent at a right angle and joined by means of a rubber tube to the gas bracket. A screw clip on this rubber enables the supply of gas to be regulated instead of having to turn the ordinary gas tap. The screw

clip is closed and the gas tap turned on full. Through the other hole in the stopper, and in the centre of it, is a piece of glass tube about 4 ins. long, open at both ends. Proceed as follows. Gently unscrew the clip, apply a light to the end of the bent glass tube until a small coal-gas flame is obtained. Now fix the stopper and fittings into position in the clamped lamp chimney. Turn on the gas gradually until full-cock by unscrewing the clip. In a few moments a flame settles on the wide tube open to the air and inside the lamp shade, and the excess of gas burns at the top of the chimney. The air drawn up through the wide tube reacts with the coal-gas in the chimney, and this is defined and limited by the resulting flame resting on the air tube. A similar action takes place in the "*atmospheric*" or Bunsen burner, and the same kind of blue flame is produced in the two cases.

(6) **That it requires a light to set fire to everything.**—This may sometimes prove a dangerous fallacy. The paper this is printed on is combustible, the air round about it is a supporter of combustion. Why, then, is not the paper burning? Because we have not set fire to it? This would be the easiest way of initiating the burning, but, if we could heat up the paper in the air to a certain temperature called the **Ignition Point**, the burning would start without applying a flame and continue so long as there was sufficient air, and the temperature was not lowered. **Before any combustible substance will commence to burn, it must be heated up in the air, to its own specific ignition temperature.** In some cases this temperature is rather low. These substances are then said to be *inflammable*. An *inflammable* substance is one of *low ignition*.

We set out to show that it was a mistake to imagine that a light is always necessary before combustion can begin. How can this be demonstrated?

Expt. 158. Take a gas-jar, invert it, and then fill with

coal-gas by collecting it upwards. Cover with a glass plate. Pour a few drops of carbon disulphide into another jar, cover with a greased glass plate, and then shake gently sliding away the glass plate momentarily to allow the air to escape. In this manner the jar becomes filled, or almost so, with carbon disulphide vapour. Now heat up a glass rod about 9 ins. long, by holding with a pair of crucible tongs in the Bunsen flame. Quickly remove the plate from the jar containing the coal-gas, and plunge in the hot glass rod (it need not be red hot), still holding the cool end. Nothing happens. Remove it and introduce into the one containing carbon disulphide vapour. At once the gas bursts into a blue flame. Consequently, a hot glass rod, and no light, has set fire to the vapour. This experiment shows that the *ignition point of different gases varies, and, that a light is not required to start combustion, so long as the required ignition temperature is obtained somehow*. The ignition point of coal-gas is about 600° C. and that of carbon disulphide vapour about 150° C.

(7) **That paraffin oil is very inflammable and will easily burn in an open saucer if a light is applied.**—This fallacy may seem to be the converse of the last. Perform the following experiment.

Expt. 159. Pour a little paraffin oil into a porcelain dish and apply a lighted match or taper. The oil will extinguish the light, and not itself burn. Why is this? Because the oil is cold and requires a little more help before it will burn, *i.e.*, the oil is not raised to its ignition point in this manner.

Expt. 160. Now, very gently warm up the oil in the dish on a tripod and wire gauze, by means of a small Bunsen flame. Apply a light from time to time. In a few moments the warm oil will burn.

Why does the paraffin oil burn in a lamp? Because it is heated up a little on the wick and this help is just what is

required. If a taper is soaked in paraffin oil, the oil will burn on it easily for a similar reason.

(8) **That chloroform is very inflammable.**—

Expt. 161. Pour some chloroform into a saucer and apply a lighted match or taper. No burning takes place. If it were inflammable, it would burn at once. The mistake arises owing to the confusion of chloroform with ether; both are anæsthetics, and ether is very inflammable, burning in an open dish when a light is held about 2 ins. away from it.

(9) **That a sniff of chloroform is sufficient to render one insensible.**—In melodrama, the villain pours a little of the fluid from a small blue bottle on to a handkerchief, holds over the mouth of the heroine, and in about three seconds she is unconscious. The liquid is supposed to be chloroform. The rendering unconscious of an individual is a more formidable business than that, and a mere sniff of chloroform is far from sufficient.

(10) **That the addition of sugar to sour fruit neutralises the acid.**—It certainly *masks* it, but it cannot *neutralise* it in the sense that caustic soda neutralises acid. Experiment will prove this.

Expt. 162. Obtain a fair amount of lemon juice of uniform sourness. Divide this into two equal portions. Add a good deal of sugar to one, and leave the other sour. Fill a burette with some caustic soda solution, add a few drops of methyl orange to each portion of juice, as indicator, and run in the caustic soda solution until one drop changes the colour in each case to yellow. The amounts of alkali run in will then be proportional to the acidities. When the experiment was tried, there was practically no difference between the burette readings of caustic soda, so that equal amounts of acid were present in the two cases although not so evident to the taste in one because of the masking effect of the added sugar.

(11) **That disinfectant, antiseptic, and deodorant are synonymous.**—A *disinfectant* is something which actually kills off the micro-organism; an *antiseptic*, one which inhibits its vital processes, or is antagonistic to its development; whilst a *deodorant* removes obnoxious gases developed by an organism, or else masks them. Corrosive sublimate is a disinfectant; boric acid and common salt are antiseptics; charcoal is a deodorant.

(12) **That a thaw bursts the pipe.**—To burst a lead pipe it is clear that a great pressure must be exerted; so that if a thaw does this, ice in melting must increase in volume. Does ice in melting yield a *larger* or *smaller* volume of water? Experiment to determine this.

Expt. 163. Pack a flask with crushed ice and fill up the interstices with water. Mark off the level of the water and ice in the neck with a piece of gum paper. Now allow the ice to melt spontaneously, or else hurry it up by heating over a flame on a tripod and wire gauze. Long before all the ice has melted the level of the water will be found *depressed* an inch or more. Evidently, ice in melting *contracts*. It is impossible, therefore, for a thaw to cause the bursting of a water pipe.

If a very thin glass bulb is filled with water, closed, and the water in it frozen by means of a freezing mixture, the glass is completely shattered. It is the *freezing* of water that bursts the pipe, but the leak is not discovered until the thaw sets in, because the ice fills up the cracks.

(13) **That steam is visible.**—The so-called “steam” issuing from the spout of a kettle containing boiling water, is really partially condensed steam.

Expt. 164. One-third fill a flask with water, place on a tripod and wire gauze, and heat to boiling. After this has been proceeding for about five minutes, one can be quite sure that all the air has been driven out, and that the part

of the flask not containing the boiling water, is filled with steam. *But this is not visible within the flask.* Something is issuing, but it is *partially condensed* steam.

(14) **That boiling water must be always very hot, or that pure water always boils at 212° F. or 100° C.—**

Expt. 165. Take a round-bottomed Jena flask, about one-quarter fill it with water, boil for about five minutes, as in the last experiment, and then simultaneously close up the neck with a good-fitting rubber stopper, and remove the flame. In a few moments the boiling ceases. Now take hold of the flask with a duster and place it inverted into a ring support over a dish or basin (see Fig. 75). On pouring cold water over it, the water commences to boil vigorously and continues to do so even when it is lukewarm. Of course, this almost cold water would not cook an

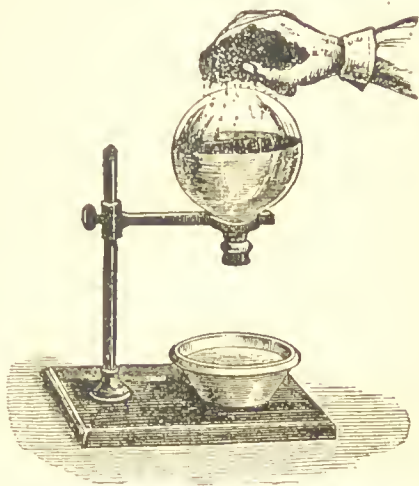


FIG. 75.— Causing Water to boil by condensing the Steam over it with cold water.

egg, or make tea, but in a physical or scientific sense it is boiling. Why is this? A liquid is said to boil when the pressure exerted by its vapour is able to overcome that of the gas above it. In the experiment steam is above the water when the flask is first stoppered. On pouring cold water over the bulb the steam is rapidly condensed and the pressure over the water reduced. Thus, although the water is cooling all the time, the temperature is quite high enough to cause its vapour to overcome the very slight pressure on the surface, and the water therefore boils. When the flask and contents are cold, it will be found extremely

difficult to remove the stopper from the neck of the flask, because of the pressure of the air on it. If, however, this is accomplished whilst the flask neck is held under water, the liquid rushes up and fills the flask, *proving that all the air had been driven out*. Consequently the remainder of the flask not containing water, must have held steam.

As diminution of pressure on a liquid lowers the temperature of its boiling point, so increase of pressure raises it. This latter is the principle of the **Thermostat**, where water is heated to a higher temperature than 212° F. or 100° C. without boiling.

(15) **That salt water takes salt out of salt meat better than fresh water.**—This is a sailor's notion. Salt meat used to be traileed in the sea at the side of the ship, and lost much salt thereby. Placed in a bucket of fresh water, it did not lose so much because the small bulk of water soon became more salty than the sea. Consequently, owing to the greater amount of sea water used in the trailing, more salt was removed. Fresh water, of course, bulk for bulk, would remove the salt better than sea or salt water.

QUESTIONS.

1. What are the chief differences between so-called "chloride of lime" and the real substance or calcium chloride? How does "chloride of lime" act as a bleaching agent?

2. How would you conclusively prove that the term "liquid," as applied to ordinary household ammonia, is quite incorrect?

3. Why is "salts of lemon" erroneously named? To what important uses is this substance put?

4. What happens when a silver article is exposed to the air? What is so-called "oxidised silver"?

5. Hard water is often said to be very "limey." Is this so? Explain carefully what quick lime, slaked lime, lime water, milk of lime, and limestone are, and how they differ.

6. (a) "The kettle is boiling." (b) "The barometer is going back." Justify the two statements and give what you consider to be better expressions to denote the two actions.

7. Discuss the pros and cons in connection with the prevalent idea that the sun shining on a fire is able to put it out.

8. Does the sun raise the dust in a room? Is the word "raise" in the expression at all justifiable?

9. Explain "combustible substance," "supporter of combustion," and "ignition point." What would happen on introducing a light into a closed room full of gas?

10. In what sense does air burn in coal-gas and how would you demonstrate that this phenomenon is possible?

11. Describe experiments which show that (a) a light is not necessary to set fire to every combustible substance; (b) paraffin oil is combustible, but not inflammable.

12. A sour gooseberry tart is sweetened with sugar and becomes eatable. How would you experiment to find out whether the acid, as such, has really disappeared?

13. By what experiment would you dispose of the notion that a thaw bursts a water pipe?

14. Reply to the following queries, supplementing your answers by experimental evidence:—(a) Is steam visible? (b) Is boiling water always at 212° F.?



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